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ROBERT BOYLE, F.R.S.
(1627–1691).
The Father of Modern Chemistry.

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The Work and Position

of

The Metallurgical Chemist

also

References to Sheffield and its Place in Metallurgy

being An Address by

SIR ROBERT A. HADFIELD, Bt.

D.Sc., D.Met., F.R.S., F.I.C., M.Inst.C.E.

Delivered before the

Sheffield Association of Metallurgists and Metallurgical Chemists

at the

Mappin Hall, The University, Sheffield
On Monday, October 24th, 1921

Illustrated with

CINEMATOGRAPH AND LANTERN SLIDES

ENGLAND

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CIVIL ENGINEERS

CONTENTS OF THE ADDRESS

SECTION NO.		PAGE
I.	Opening Remarks	9
II.	Sheffield's Work in the Past and During the War Sheffield's Work History of Sheffield. Industrialists and Educationalists. War Work.	11
III.	Sheffield Association of Metallurgists and Metallurgical Chemists Its Aims and Objects.	16
IV.	The Chemist Chemical Societies and the Development of Chemistry. Modern Laboratory Practice. Training and Work of the Chemical Engineer. The Ramsay Memorial. Sir James Dewar. The Influence of Chemistry in the War. The Position of the German Chemist in the Past.	19
V.	The Indebtedness of the Metallurgist to Science The Aid of Science to Metallurgy. The Japanese Research Institute for Iron and Steel.	31
VI.	Metallurgical Literature	34
VII.	Metallurgy and Poetry	36
VIII.	General Reference to the Lecturer's Research Work	39
IX.	Manganese Steel A brief reference to its Invention and Application.	45
X.	Low Hysteresis Steel A brief reference to its Invention and Application.	49

SECTION NO. PAGE

XI. Federation of Engineering Interests . . . 52
United Engineering Council.
Federation of Engineering Institutions.
The Engineers' Clubs in London and New York.

XII. Electrical Power 58
Niagara Falls.
Victoria Falls.

XIII. Rapid Cinematography 66

XIV. American Railroads and their Long Trains . 67

XV. An Appreciation of Ancient Research Workers . 69

XVI. Royal Society 71
Early History of the Royal Society.
Francis Bacon.
Bishop Sprat's "History of the Royal Society."
Lord Brouncker's Experiments on the Recoiling of Guns.
The Charter Book and Signatures.
Members of the Engineering Profession who have been Fellows; William Penn, Benjamin Franklin and William Pitt (Earl of Chatham).
Importance of Scientific Research.

XVII. Conclusion 93

Summary of Papers and Addresses by Sir Robert Hadfield, Bt. 95

Description of Exhibits 97

PHOTOGRAPHS AND CINEMA PICTURES

Section No.	Plate No.	Page No.	Description
I.	1	9	Photograph of the American Delegation of Engineers who visited London in June, 1921, together with their Signatures.
II.	2*	11	Portrait of Huntsman. Huntsman Cementation Furnaces, built about 1750.
	3	11	Portrait of four generations of the Bessemers.
	4*	12	Sir Henry Bessemer's letter to the Lecturer, January 11th, 1897.
	5*	15	British Expenditure on Munitions in the Great War.
	C1*		Diversion of the River Don at Tinsley, carried out during the War.
	C2*		Firing of 10½ c/m (4⅛ in.) long range Gun, and Armour-Piercing capped Projectile perforating Armour Plate.
III.	6*	18	Comparison Table of the number of Students at the Sheffield University in 1886, 1893 and 1921.
IV.	7	22	Chemists of note from about 1493 down to the present time.
	8	22	Metallurgical Chemists of note.
	9	24	Portrait of the late Sir William Ramsay, F.R.S.
	10	26	The Royal Institution Laboratory, showing Sir James Dewar, F.R.S., at work.
	11	27	The Royal Institution Laboratory, with Professor Faraday at work.
	12	27	Faraday lecturing before the Prince Consort.
	13	28	Portrait of Robert Boyle, F.R.S., the Father of Modern Chemistry.
	14*	29	Portrait of Professor A. Ledebur of Freiburg.
	15*	30	Professor Ledebur's Laboratory.

Section No.	Plate No.	Page No.	Description
V.	16	32	The Japanese Research Institute, opened July 9th, 1921.
VIII.	17	40	Professor Osmond's first letter to the Lecturer, October 2nd, 1889.
	18*	40	Translation of Professor Osmond's Letter.
IX.	19	46	Photographs of various types of Helmets used in the War.
	20*	46	Illustration from *Life*, showing sections of the various Allied Armies with their Helmets.
X.	21	50	Small and large Transformers of Low Hysteresis Steel.
	22*	51	Letter from Mr. S. E. Fedden, with record of tests in 1905, 1912, 1915, up to the present time.
XI.	23	56	Engineering Building and Club, New York.
	24	56	Engineers' Club in London, opened August, 1921.
XII.	25*	62	Map of Central Africa.
	26	62	The Victoria Falls from the Eastern Extremity.
	27	63	Aeroplane View of the Victoria Falls.
	28	64	The Victoria Falls, Profile Point.
	C3*		Cinema pictures showing the Victoria Falls at their full width, nearly one mile.
XVI.	29	72	Portrait of Francis Bacon.
	30	77	Engraving by Hollar in 1667, showing King Charles II, Lord Brouncker, the first President of the Royal Society, and Sir Francis Bacon.
	31	85	Signatures of Past Fellows, from the Charter Book, 1754 to 1758.
	33	85	Portraits of the Founder and some of the Past Notable Fellows of the Royal Society.
	34	85	Signatures of some of the Past Notable Fellows of the Royal Society.
XVII.	32*	94	Motto.

* Shown at the Lecture only.

Section I

OPENING REMARKS

May I commence this Address by saying that its presentation to you at this Opening Night of your Session is largely due to pressure brought to bear upon me by your Past President, Dr. W. H. Hatfield, your present President, Mr. P. B. Henshaw, and one of your Members of Council, Mr. T. G. Elliot, F.I.C.

When the Invitation was given to me I begged to be excused, not that I did not greatly appreciate the honour of being asked, but I hardly felt that I could do justice to the occasion, as owing to the pressure of ordinary work there was but comparatively little time for the preparation of an Address which should adequately present any special subject for your consideration.

Besides, owing to recent contributions of one kind or another, it is somewhat difficult to avoid going over old ground. As far as I can do so in my Addresses and Papers I always try to aim at contributing something new and something original. In these days of fierce mental competition, with so many minds often at work on the same problem, it is not easy to put forward points of novelty.

I explained this view to those whose names I have just mentioned, but they suggested with friendly pressure that if it was not possible to write an entirely new Address, I should make use of some portions of the one I delivered not long ago to the Deputation from the Engineering Societies of the United States who came over to London in connection with the presentation to me of the John Fritz Medal. You have, through your President, been kind enough to accept my contribution in this way.

The picture (Plate 1) thrown on the screen shows the Members of the Deputation in a photograph which they kindly presented to me. I call your special attention to Mr. Ambrose Swasey, 75 years of age, and the generous donor of some $640,000 for Research in America. He is one of the leading Engineers on the other side, and amongst other things has built all the big telescopes in U.S.A., at Mount Wilson, Mount Hamilton, and elsewhere.

Let me at once say and emphasise most strongly that it gives me great pleasure to try and be of any service in assisting those in my own line of work, that is the Science of Metallurgy,

who have helped Sheffield so considerably in the past and are also doing so as regards its future.

Amongst the many congratulations I have received from those at home and abroad in connection with the Award of the John Fritz Medal, none was more greatly appreciated than that dated February 3rd, 1921, and sent to me as representing the good wishes of the Scientific side of our City. I refer to the official communication signed on behalf of those in our City interested in Science by two friends of long standing of us all, I refer to Professor W. Ripper, Dean of the Faculty of Engineering at the Sheffield University, and Dr. Cecil H. Desch, Dean of the Faculty of Metallurgy. I take this opportunity of expressing most hearty thanks to them and to you all for that very kind message.

Whilst referring to this subject, I should like to make a personal reference which I am sure will be of interest to the audience. Amongst the previous recipients of the honour in question were Lord Kelvin in 1905 and Sir William White in 1911. In Sheffield the name of Sir William White has been a household one. He was popular with all of us; he stimulated and helped on Scientific progress in a remarkable degree. I felt much moved, therefore, when Lady White herself wrote me a letter of good wishes, and in which she made some touching references to Sir William, whose name will ever be remembered in connection with his renowned work on behalf of the Bulwarks of our National Defence, the Navy, as well as Engineering Science generally.

As regards the Address to which I have already referred, judging from the large number of letters of thanks received from those at home and abroad, it has, as I trusted and hoped it would do, even if in a small and humble way, also helped to cement further the good feeling between Engineers of all kinds and classes of the Anglo-Saxon speaking races. Instructions, too, have just come from the Committee of the Engineering Societies in New York asking me to prepare for them a further five hundred copies for circulation amongst the Engineers of that country.

PLATE I.

The Deputation of American Engineers which visited London, June 29th, 1921.

Robert A. Cummings Charles T. Main Jesse Merrick Smith F. B. Jewett William Kelly
Ira N. Hollis Arthur J. Wright Ambrose Swasey Charles Rand John R. Freeman

Section II

SHEFFIELD'S WORK

We have every reason to be proud of the great work accomplished by our City in the past, and of the place it occupies in our Empire. Many of the great modern improvements in the Science of Metallurgy have been initiated or first carried into practical effect in Sheffield. Can we maintain our position in the future ? I answer, Yes, most emphatically, that is if Sheffield will make full use of the Educational means in its midst, including chiefly that centre of intellectual life, our University, from which ordered progress chiefly comes. We are specially fortunate in having Sir Henry Hadow, one of our greatest Educationalists, to preside over its policy and influence its destinies.

I wish every success to our City and its future. If we are true to ourselves I am not alarmed about the outlook. Whilst, as Lord Rosebery said not long ago, some appear to succeed in life without any form of academic discipline, yet on the other hand we have the remarkable testimony of probably the greatest man in the War, Marshal Foch, who, when asked whether he found his academic studies to be of any immediate service on the field of battle, said " No, not altogether, but they give me confidence." It is this confidence in life which is so important and so absolutely essential—the quiet confidence which comes from knowledge, and knowledge is Power.

Sheffield can indeed be proud of its Sons in the past. The quality of our products was evidently well known or our great English poet, Chaucer, would hardly have referred to them nearly six centuries ago. Speaking of the Metallurgical side, Huntsman, whose portrait is shown on the screen on Plate 2, and many another true honest worker, rendered wonderful aid when he helped us by the foundation of his method of producing crucible cast steel. A picture of the Huntsman Cementation Furnace is also shown in Plate 2. The Bessemer process might have come to grief but for the aid, in its early stages, of some prominent Sheffield Citizens. It was the application of this System of producing Steel which helped to revolutionize the world, and make possible the building of railroads on the present gigantic scale.

I have pleasure in showing on the screen this evening, a portrait of Sir Henry Bessemer (Plate 3), his son, grandson,

and great-grandson. At the foot will be seen a note in Sir Henry's own handwriting.

Plate 4 shows a personal letter which I received from Sir Henry under date January 11th, 1897. This is also of considerable interest, specially as he says that in a week from that date he would celebrate his 84th birthday.

HISTORY OF SHEFFIELD

No reference to the Industrial life of Sheffield is complete without mention being made of the Cutlers' Company of Hallamshire, which has done so much in the past for our City. Its official foundation was in 1624, so this is the 298th year of its corporate existence, since Robert Sorsby became the first Master Cutler. I am sure the Society will offer its heartiest congratulations and best wishes to our new Master Cutler, Mr. Marmaduke Wardlow.

In 1732, John Wesley paid his first visit here, and the first Sheffield Newspaper, Lister's *Sheffield Weekly Journal* was founded in 1754. Apart from those concerned with our industrial or civic life, amongst the names of past worthies in the history of Sheffield may be mentioned Ebenezer Elliott; Samuel Bailey, the Bentham of Hallamshire; Hunter, the Historian; Roebuck, who was of Sheffield blood; Chantrey, the Sculptor; Montgomery, the Poet; Sterndale Bennett, the Musician; Charles T. Gatty; Earnshaw, a Senior Wrangler, and many others.

Two of the great workers who helped to guide Sheffield University's Educational career are happily still with us. I refer to Dr. W. M. Hicks, F.R.S., and Professor W. Ripper, M.Inst.C.E.; and another popular friend of us all, alas, gone before—I refer to Colonel H. Hughes, who did so much for our City and its progress.

As regards Sheffield itself, as Lord Palmerston once said when on a visit to us, it is "A Black Picture set in a Golden Frame." Our surroundings are hardly to be surpassed either in beauty or historic interest. We have Chatsworth, Haddon, Hardwick, Bolsover, and Castleton; the rugged and wild Peak District is near at hand; Wharncliffe Crags; the noble estates of Welbeck and Clumber, whence stretch for many a mile the glades and woodlands of Sherwood Forest where once rang the

FOUR GENERATIONS OF THE BESSEMER FAMILY.

This family Photograph was taken in the Conservatory of My Grandson's House, at Roseland, near Southampton in July 1896. it represents Myself, My Eldest Son Henry, and his eldest son Henry, and his little boy who is called "Henry the Fourth" all being eldest sons, of eldest sons,

Yours very Truly H. Bessemer.

shouts of Robin Hood and his merry men. Most of these are almost within sight of our smoky City.

We have in Sheffield now no less than half a million inhabitants to say nothing of the further large populations immediately around us.

In historic importance there are not many manufacturing Cities which can proudly look so far back as we can. In proof of this statement I recall again that the Great National Poet, Chaucer, recognised the merits of our products, no less than 560 years ago.

As regards historic importance, I reminded a Technical Society visiting us last year that the ill-fated Mary Queen of Scots was for some sixteen years a prisoner at the Castle and Manor House under the Earl of Shrewsbury. Strange to say, during that time Sheffield experienced an earthquake which was so considerable that the floor of Queen Mary's bedchamber fell out, causing the Earl to say that it was a visitation of God upon her. Only a few weeks ago I paid a visit to that unhappy spot, Fotheringay Castle, where the Queen was taken to meet her doom. This Castle was razed to the ground by her son, James II, and little is left beyond a heap of stones.

Incidentally, it may interest those present who happen to be members of the Iron and Steel Institute to know that the charming hostess Madame Schneider, who recently received us so graciously at Le Creusot, is a descendant of James II in a direct line through the first Duc de FitzJames Berwick and Albe, the son of James II and Arabella Churchill. The Duchess de FitzJames was Madame Schneider's great-grandmother.

INDUSTRIALISTS AND EDUCATIONALISTS

Speaking of the past regarding Sheffield's Industrialists and Educationalists, such men as Brown, Cammell, Firth, Vickers, Reynolds, Sanderson, Mappin, Stephenson, Jessop, Rodgers, Ellis, and a host of others, have all helped to sustain our reputation for supplying products of the highest degree of excellence.

On the active Educational side we have Earnshaw and Sorby, also three others who stand out prominently and whose names will go down to posterity with great respect, I refer to Dr. Hicks, but for whom we should probably have had to wait a long time for the University now firmly established in our midst ;

Professor Ripper, who in season and out of season, has done so much for the education of the Technical man; and Professor J. O. Arnold, who has ever held high the banner of the Science of Metallurgy, and succeeded in getting established a distinct hall-mark for the Metallurgist in its Faculty.

In Chemistry in the past, amongst others we have had Messrs. Baker, Allen, Williams, O'Shea, and now Professor W. P. Wynne, F.R.S., who has for so many years most faithfully served Sheffield University. He has justly been honoured with a seat on the Council of the Royal Society, in fact he and I, both Sheffield men, have been serving together on that body for the usual term of two years.

WAR WORK

On the subject of the War work performed by Sheffield, I am indebted to Sir Graham Greene, the Head of the Organising Department of the Ministry of Munitions during a large portion of the War period, for the following information. Whilst unable to give the complete values or tonnages of the enormous output of Sheffield and District during the War on behalf of our Sea, Land, and Air Forces, to say nothing of the efforts of tens of thousands of our citizens in and around who fought the good fight for our Empire, Sir Graham has been able to tell me something of what was accomplished in Sheffield on behalf of Munitions, also by the National Factories in this district, of which my Firm, Messrs. Hadfields Limited, and Messrs. Thomas Firth and Sons, Limited, each ran one for the benefit of the Nation. It will be remembered that Rotherham, Barnsley, and Chesterfield did their best, too.

The total approximate output of Shell from the Sheffield National Factories amounted to no less than one and a half million Shells, many of these of comparatively large calibre.

Then through the Sheffield Board of Management, very large quantities of Shell components, gauges, trench mortars, and ammunition, gun forgings, helmets, ammunition boxes, grenades, brass rod, copper strip, and other products were turned out.

Housing schemes were also carried out by the Sheffield Corporation, with grants from the Ministry of Munitions—in all, nearly 1,500 houses and cottages—in addition to Hostels and Colonies for over 2,000 Workers.

It is interesting to add that the total expenditure by the Ministry of Munitions, on Munitions and materials (including advances to Contractors and Capital Expenditure) during the years 1915-1919 amounted to no less than £1,858,213,180. Plate 5 now thrown on the screen will perhaps bring home what this really means. The figure, gigantic as it is, is comparatively a small portion of the stupendous total sum expended by our Country, irrespective of that by our Allies. Seeing that practically all the value covered by the figure relating to Munitions was blown into the air, it is no wonder that, in every Country, Industrialists—and by this I mean Employer and Employed—whilst endeavouring to recover from this enormous waste—be it remembered, too, a small part only of the gigantic waste by victor and vanquished alike—have not yet been able to accomplish this task, nor is it possible to expect complete restoration for many a long day.

In order to bring home to our minds a conception of what this total expenditure has meant, if we take the average price of Pig Iron before the War at £3 per ton, then the expenditure on Munitions of the same amount of money as that I have just mentioned would alone have purchased over 600 million tons of Pig Iron. Assuming the World's output of Pig Iron averaged 50 million tons per annum, it will be seen that it would have taken all the blast furnaces in the World twelve years to produce this quantity of Pig Iron.

SHEFFIELD ASSOCIATION OF METALLURGISTS AND METALLURGICAL CHEMISTS

As regards the Society before which I have the honour to give this Address, the Sheffield Association of Metallurgists and Metallurgical Chemists, and to whom I have again to offer my thanks for the compliment they paid me in making me an Honorary Member on their foundation, this body, as you know, was established about the end of 1917 and arose out of various meetings of Sheffield Chemists, called together from time to time to discuss questions of special interest to them.

One of the chief reasons which led to the formation of the Association was the feeling that it would be to the general mutual advantage to have regular meetings, and if possible to form a Club for Metallurgists, Metallurgical Chemists, and others interested in the Scientific side of the Industries of the district. As you know, it has not yet been possible to find suitable premises to carry out the latter object, nor in these parlous times can this be expected. The nearest approach to this desirable object is that the Association has secured rooms at the Royal Victoria Hotel, a central position and near the Station. One room serves as a Library and Reading Room, and another for weekly meetings of the Association.

The Library is well stocked with books, its Catalogue being given on page 9 of the Annual Report for 1920, as well as with most of the leading Metallurgical Journals and Periodicals, both English and Foreign. One of the Members of my own Company's Research Staff, Mr. G. B. Willey, is the Librarian. We all owe him a debt of gratitude for carrying out these honorary duties so satisfactorily and at the expenditure of so much time and trouble on his part.

In the past you have had excellent Opening Addresses. Last year you were addressed by Sir Henry Fowler, and at other times by Dr. J. E. Stead, Dr. H. C. H. Carpenter, Professor G. W. Fearnsides, Dr. W. Rosenhain, Mr. Harry Brearley, Dr. Leslie Aitchison, and others.

No less than 24 Addresses and Papers were presented during the Session of 1919, and about the same number during 1920.

I am glad to learn that the attendance at the Monthly Meeting varies from 100 to 200 and at the Weekly Meeting from 50 to 80.

You are fortunate in your list of Presidents, who have been Dr. W. H. Hatfield, who was your first President and who has done so much for Metallurgical Research Work generally, Dr. T. Swindon, Mr. J. H. S. Dickenson, and now Mr. P. B. Henshaw, as well as in your Honorary Secretary, Mr. G. R. Bolsover, and Mr. L. Dufty, your Honorary Treasurer.

The Membership Roll of the Association at the present time totals 234, and is made up of 128 full Members, 73 Associates, 4 Associate Members, and 29 Honorary Members. May you continue to increase in numbers and gather strength. No band of men, representing Scientists and Technical Experts, did more in the War than the Chemists, and the Nation is very grateful.

SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS

Whilst speaking of local Societies and the help they give in encouraging progress and research, may I say that it is with no little satisfaction that I look back to the occasion when I was the first occupant of the Presidential Chair of the Sheffield Society of Engineers and Metallurgists, now nearly thirty years ago, that is in 1894. I well remember giving a Conversazione at the Technical School, as it was then called, when I read a Presidential Address, I believe the first I had made, and I did so with much trepidation. On looking over my remarks, I think that even to-day they would meet with your approval.

At this Gathering was organised probably the first complete Scientific and Technical Exhibition of Metallurgical and other Apparatus which had been held in the City. Sir Frederick Mappin, Sir Henry Stephenson, Professor W. Ripper, and Professor J. O. Arnold, and Mr. F. K. Knowles, for many years the Secretary of the Society, entered heartily into the spirit of the affair and helped to make the occasion a great success.

I notice that in my remarks at that time I pointed out that the Sheffield Technical School, as it then existed, had a Roll Call of some 151 Day and 490 Evening Students, or a total of 641 as compared with the total of 99 in our first year, 1886-87. At the present time the grand total is not less than 3,546, thus showing a splendid increase.

As the point is one of considerable local interest, I am throwing upon the screen Plate 6 giving the data in tabular form.

THE FOLLOWING TABLE SHOWS THE NUMBER OF STUDENTS IN ATTENDANCE DURING THE SESSION 1920-1

	Faculty	*Number*	
Day Students ..	Arts	427	
	Pure Science	222	
	Medicine	161	
	Law	26	
	TOTAL FOR WESTERN BANK ..		836
	Engineering	723	
	Metallurgy	135	
	TOTAL FOR ST. GEORGE'S SQUARE		858
	TOTAL DAY STUDENTS FOR UNIVERSITY		1,694
Evening Students	Engineering	1,045	
	Metallurgical	717	
	Arts and Law	90	
	TOTAL EVENING STUDENTS FOR UNIVERSITY		1,852
	GRAND TOTAL		3,546

THE FOLLOWING IS A COMPARISON BETWEEN THE ROLL CALL OF 1886, 1893 AND 1921

	Day	*Evening*	*Total*
1886	—	—	99
1893	151	490	641
1921	1,694	1,852	3,546
Increase	1,543	Increase 1,362	Increase 2,905 over 1893

The influence upon our Civic life of this great increase in the number of those being trained in a scientific manner must be of the highest importance, and I congratulate very heartily those, who in the past had that faith in them which moves mountains, upon the results of their labours. Two names stand out very prominently, Dr. Hicks, F.R.S., and Professor W. Ripper, M.Inst.C.E., who still continue to take an active interest in Sheffield's welfare. We offer them our heartiest congratulations upon their life's devotion to this work in our midst.

THE CHEMIST

As you are aware, I am, in my Address this evening, giving preference to the Chemist, an important section of whose work is performed by the Metallurgical Chemist. Metallurgy involves many branches of Science; it is quite impossible to cover all of them in one Address. I have therefore said little regarding Metallography, which owes its origin to that great Sheffield man of the past, Dr. H. C. Sorby, F.R.S., and in whose honour and memory you are I believe next week to have a special Lecture in this Hall.

There is no man who works harder than the Chemist, and during the War he showed his grit over and over again in "sticking at it" and overcoming difficulties innumerable. The Sheffield Chemist was no exception and braved the fierce storm under many adverse circumstances and conditions as well as the best of us.

The Chemist's work is arduous; in making his analyses he is often performing numberless operations, all of them requiring great care and the slightest failure in any one of which will completely vitiate the final result. There can be no "cooking" of figures; accuracy must reign supreme. During my life I suppose that hundreds of thousands of analytical results have come before me and I am delighted to say that I never remember a dishonest one being presented. I am also proud to say that on recently referring to my Laboratory and Experimental Notebooks, going back as far as 1882, I find many hundreds of my own analyses, the accuracy of the figures in which to-day I see no reason to doubt.

My own training as a Chemist was under Mr. William Baker, then Professor of Chemistry at the Collegiate School, Sheffield, where I was educated. His son, Mr. C. K. Baker, still practises in Sheffield. Later on, I received further instruction from a Chemist of considerable prominence, the late Mr. A. H. Allen of Surrey Street. Mr. William Baker used to give us most delightful weekly Lectures in Chemistry each Saturday morning at nine o'clock at the Collegiate School, then under the able guidance of the Rev. G. B. Atkinson, M.A., who afterwards became a prominent coach at Cambridge. Evidently, my mind was particularly attracted by the wonderful Science of Chemistry, then budding

forth into greater and still greater prominence and importance, for I never remember once being late at School for these Saturday morning Lectures, which were illustrated by numerous experiments, the true way to interest the mind of the boy. It was with special glee the boys occasionally witnessed some mishaps which resulted in unexpected explosions. I remember one in which the Glass Tube from some chemical apparatus being employed was shot up with considerable violence and stuck in one of the beams of the roof. For many a long day it was the aim of the boys to fire paper arrows and often "projectiles" from catapults to bring this down, but no one succeeded. For anything I know this tube may be there to-day.

In 1875, to my great delight, after having struggled hard, I obtained both the prizes offered in "Natural Science," as it was termed, that is, one for Practical Chemistry and the other for the best paper on the Lectures of that year.

A useful method adopted by the Governors of the Collegiate School in those days was a "mark holiday" each fortnight. During this period those boys obtaining a minimum of 60 marks out of a possible 120 received a half holiday on one Monday in each fortnight. Even the laggard strove to get his 60 marks to avoid being confined in School on that afternoon.

Referring to Lectures accompanied by experiments, it may be a strong statement to make, but I think that it ought to be possible for citizens of all classes of the Empire to have opportunities, similar to those I have mentioned, given to them of hearing Lectures on Chemistry and Physics, and seeing demonstrations carried out. The wonders of Nature's countless secrets gradually being unravelled by Man are best brought home to the mind by Experiment in such a way as to encourage and stimulate thought.

Two of Pepper's Books, one "The Play-book of Science," and the other "The Play-book of Metals," had a remarkable influence, too, on my mind. The former book has been re-written by Dr. Mastin, and about seven years ago I presented some 75 copies to the Education Committee of the various Schools of Sheffield, all of which were distributed, and I believe with useful effect. The Senior Inspector of Schools, Mr. T. W. Quine, four years ago wrote to me from the Sheffield Education Office saying that the distribution had been found useful in supplying Scientific information beyond that of the ordinary School Book. The Books presented had been used by Scholars in Standards VI and VII, and practically all the Head Teachers stated that more

copies would be genuinely appreciated. The following is an extract of a letter received by Mr. Quine from one of the Head Teachers :—

" The Books on Science presented by Sir Robert Hadfield have amply fulfilled the purpose of stimulating a love for Science and of prompting enquiry in the Pupil's mind as to the why and wherefore of Natural phenomena.

" They have proved most useful to Pupils of ages from twelve to fourteen years, specially to those who have been able to attend the classes for Practical Science.

" The matter in Pepper's ' Play-book of Science ' is so set forth as to create interest and pleasure, where the ordinary School book fails."

I am glad to see that Professor N. T. M. Wilsmore, an able Australian Scientist, in his valuable Presidential Address on " The Present Position of Chemistry and Chemists," delivered before Section B (Chemistry) of the Australasian Association for the Advancement of Science, held in Melbourne early this year, has expressed a similar approval of Pepper's Works. As he says, although these could never have been text books, they were made of such great interest for the young mind as to be of the highest service.

CHEMICAL SOCIETIES AND THE DEVELOPMENT OF CHEMISTRY

I should like to refer to the splendid work being done in England by the three main Societies interested in this branch of Science, the Chemical Society, founded in 1841 ; the Society of Chemical Industry, founded in 1881 ; and the Institute of Chemistry, founded in 1877, the entrance to which is a proud privilege. I am glad to say we have a number of Fellows in Sheffield, including Dr. T. Baker, Dr. F. Ibbotson and Professor W. P. Wynne, Professor C. H. Desch, Mrs. C. H. Desch, Messrs. T. G. Elliot, C. K. Baker, J. Evans, J. Haworth, J. H. Huxley, J. Imrie, B. Methley, C. T. Nesbitt, W. J. Rees, and G. B. Willey.

As regards the historical side of Chemistry it would perhaps be too ambitious an effort to try and bring before you the names of all the leading Metallurgists and Chemists of the last few hundred years. I shall, however, make an attempt to show you

in the following Table the names of the Great Leaders, asking you to forgive in it any incompleteness, as there must necessarily be. Perhaps, on some future occasion, I may be able to bring before you the portraits of these famous men who have made that branch of Science, in which we are so much interested, what it is to-day.

I have prepared from this Table, Plate 7, Section I, which shows the names and dates of the notable Chemists from about 1493 down to the present time. The names of the Metallurgical Chemists are given separately in Plate 8, Section II. The "type" classification is based on the method suggested and introduced by Sir William Tilden, F.R.S., in his valuable book, "Famous Chemists; the Men and their Work."

Another work of similar merit is that by Sir Edward Thorpe, F.R.S., on "The History of Chemistry," covering from 2000 B.C. to A.D. 1910. Sir Edward points out that Chemistry as an art was practised thousands of years before the Christian era, but as a Science it dates no farther back than the middle of the Seventeenth Century. Although the monumental records of Egypt and the accounts left by Herodotus and other writers show that the ancient Egyptians had a knowledge of processes essentially Chemical in their nature, yet there is no certain evidence that the Egyptians ever pursued Chemistry in the spirit of Science, or even in the manner which they and the Chaldeans followed, for example, Astronomy and Mathematics.

It is believed that the origin of the word "Chemistry" was from "chemi," meaning the "black land," the ancient name of Egypt. It was known as the "black art" which may have signified "Egyptian art" rather than that of doubtful nature.

Thorpe traces in a most graphic and interesting manner the rise of Alchemy; the Philosopher's stone; Iatro-Chemistry; and Phlogistonism. We then come to Lavoisier and La Revolution Chimique; the Atomic Theory of Dalton and others which superseded previous conceptions; and then we have the beginnings of Electro-Chemistry; the foundations of Organic Chemistry, and the rise of Physical Chemistry, into which I need not enter this evening.

CHEMISTS

Iatro-Chemistry

Roger Bacon	1493–1541
Paracelsus	1494–1555
Agricola	1490–1555
Glauber	1604–1668
Van Helmont	1577–1644

The Beginnings of Modern Chemistry

*Robert Boyle	1627–1691
Mayow	1615–1679
Boerhaave	1668–1738
Hales	1677–1761

* The Father of Modern Chemistry and the original user of the word "Analysis."

The Phlogistians

Stahl	1660–1734
Black	1728–1799
Cavendish	1731–1810
Priestley	1733–1804
Scheele	1742–1786
Bergman	1735–1784
Cronstedt	1722–1765
Réaumur	1683–1757

The Antiphlogistic Revolution

Lavoisier	1743–1794
Berthollet	1748–1822
Vauquelin	1763–1822
Klaproth	1743–1817
Berthier	1782–1843

Electricity in the Service of Chemistry

Franklin	1706–1790
Davy	1778–1829
Wollaston	1766–1826
Faraday	1791–1867
Henry	1797–1878
Hare	1781–1858
Silliman	1772–1860

Laws of Combination and the Atomic Theory

Proust	1755–1826
Dalton	1766–1844
Gay-Lussac	1778–1850
Berzelius	1779–1848
Thénard	1777–1857

Molecule and Atom Defined

Avogadro	1776–1856
Cannizzaro	1826–1910
Prout	1786–1850

Early Attempts at Classification

Dumas	1800–1884
Liebig	1803–1873
Hofmann	1818–1892
Bunsen	1811–1899
Playfair	1819–1898
Roscoe	1833–1915
Kirchhoff	1824–1887
Wöhler	1800–1882

Theories of Chemical Action and Constitution of Molecules

Williamson	1824–1904
Frankland	1826–1899

Classification and Nature of Elements

Crookes	1832–1919
Mendeléeff	1834–1907
Ramsay	1852–1916
Travers	
Moseley	
Aston	

Physical Chemistry

Rumford		1753–1814
Dulong		1785–1838
Mitscherlich		1784–1863
Graham		1805–1869
Tyndall		1820–1893
Maxwell		1831–1879
Abel		1827–1902
Arrhenius	Morley	
Bancroft	Nernst	
Clarke	Onnes	
Cooke	Ostwald	
Crossley	Porter	
Donnan	Rayleigh	
Gibbs	Remsen	
Haber	Richards	
Harker	Sabatier	
Hatschek	Thomson, J. J.	
Kelvin	Thorpe, J. E.	
Langley	Threlfall	
Langmuir	Walker	
Lockyer	Wenzel	

Stereo-Chemistry

Dobbie	
Le Bel	
Van t'Hoff	1853–1911

Chemistry of the Radio Active Elements

Bragg, W. H.	Becquerel
Bragg, W. L.	Rutherford
Curie	Soddy

Organic Chemistry

Baeyer	Gerhardt	Pelouze
Berthelot	Haller	Perkin
Cahours	Kekulé	Richter
Chevreul	Ladenburg	Robertson
Debus	Laurent	Thorpe, J. F.
Fischer, E.	Moureu	Wurtz
Frémy	Pasteur	

Modern Chemistry

Armstrong	Frankland, P.	Pope
Baker	Jackson	Scott
Beilby	Lowry	Tilden
Dewar	Meldola	Wynne
Dixon	Morgan	Young
Forster	Perkin, W. H., Jun.	

SECTION I

This "type" classification is based on the method suggested by Sir William Tilden

METALLURGICAL CHEMISTS

CHIEFLY MODERN

British

Abel
Aitchison
Allen
Andrew
Andrews
Archbutt
Arnold
Baker
Bannister
Bauerman
Bayley
Bell, Lowthian
Beringer
Bessemer
Brearley
Carpenter
Crookes
Darby
Desch
Dickenson
Dunn
Edwards
Elliot
Fletcher
Forbes
Friend
Gilchrist
Gowland
Gray, Watson
Greenwood
Hanson
Harbord
Hatfield
Haughton
Heycock
Holloway
Hudson
Humfrey
Huntington
Ibbotson
Johns
Lantsberry
Law
Longmuir
Louis
MacFarlane
McCance
McWilliam
Mond
Moore
Mushet, David
Mushet, Robert
O'Shea
Parry
Percy
Pettus
Philip
Phillips
Pickard
Ridsdal
Riley
Roberts-Austen
Rogers
Rose
Rosenhain
Saniter
Siemens
Sillars
Snelus
Sorby
Stansfield
Stead
Swinden
Thomas
Thompson
Turner
Whiteley
Williams

American

Blair
Buck
Bullens
Burgess
Cain
Camp
Campbell
Cushman
Dana
Demorest
Douglas
Drown
Eggleston
Furman
Heath
Hibbard
Hofman
Howe
Hunt, Alfred
Hunt, Sterry
Jeffries
Johnson
Kelley
Keep
Low
Mathesius
Mathewson
Merica
Metcalf
Moldenke
Peters
Rawdon
Richards
Rickard
Ruder
Sauveur
Scott
West
White

French

Baraduc-Muller
Breuil
Brustlein
Campredon
Charpy
Chesneau
Chevenard
De jean
Dupuy
Dumas
Euverte
Gautier
Girod
Grenet
Gruner
Guillet
Guillaume
Héroult
Le Chatelier
Martin
Moissan
Nicolardot
Osmond
Portevin
Pourcel
Robin
Werth

Swedish

Akerman
Benedicks
Brinell
Eggertz
Ekman
Gahn
Louis de Geer
Goranson
Mosander
Rinman
Selfstrom
Swedenborg
Wallensins
Westgren
Wiborgh

Italian

Giolitti
Villavecchia

Japanese

Honda

Russian

Belaiew
Tschernoff

German and Austrian

Bauer
Behrens
Borchers
Dichmann
Fresenius
Goerens
Guertler
Hanemann
Heyn
Juptner
Ledebur
Martens
Muller
Neumann
Oberhoffer
Orthey
Osann
Ruff
Schnabel
Tammann
Wedding
Wust

Swiss

Weiss

During my recent tour in France with the Iron and Steel Institute, I had an interesting interview with the well-known Metallurgist, Monsieur G. Charpy, who in addition to his Industrial work is now Professor of Metallurgy at the School of Mines, Paris. He has devised important methods for improving the organisation and output of Metallurgical Laboratories. By subdivision and specialising the work in the Chemical Laboratory, Monsieur Charpy is able to put through a much larger number of analyses than in the ordinary way. He has already contributed a Paper entitled "Essais d'Organisation Méthodique dans une Usine Métallurgique," which was read before the Société d'Encouragement pour l'Industrie Nationale, on March 8th, 1919, and upon which important contributions to the Discussion were made by the President of that body, also by Professor H. le Chatelier.

Before writing this Address, I asked Monsieur Charpy for any new information he had upon the subject. He referred me to the above-mentioned Paper, also adding that he is going to present a note on the subject at the next Meeting of the Society of Applied Chemistry in France.

If I might make a suggestion to your President and Secretary, would it not be a good plan to ask Monsieur Charpy for a Paper to your Society, even if he were not able to present it in person. Perhaps a special invitation could be sent to him to visit our University, as he told me that he would like to have information about any special matters relating to Apparatus or Laboratory equipment.

In the Paper I have mentioned already, contributed by Monsieur Charpy, he fully describes his methods, which appear to consist in a modified application of the Taylor method, and the systematisation of Steel-works analysis by defining all the operations in advance, and making them as mechanical as possible. Monsieur Charpy states that five operators were able to make twenty-five analyses of each of five elements (Phosphorus, Silicon, Manganese, Chromium and Nickel), that is, 250 determinations, in two shifts of eight hours each, without undue hurry, in fact several periods of rest were allowed.

In the Paper are stated the programme worked to, and the detailed operations of each assistant, together with practical suggestions for facilitating the work, eliminating fatigue and the prevention of errors.

TRAINING AND WORK OF THE CHEMICAL ENGINEER

Whilst speaking of the Training and work of the Chemist, I may add that whilst President of the Faraday Society I arranged, in March, 1917, a Symposium upon the Training and Work of the Chemical Engineer.

In my opening remarks on that occasion I pointed out the necessity for this Country paying every possible attention to the Branch of Science termed Chemistry, and the rising generation of all ranks and classes being offered every facility for the best possible training.

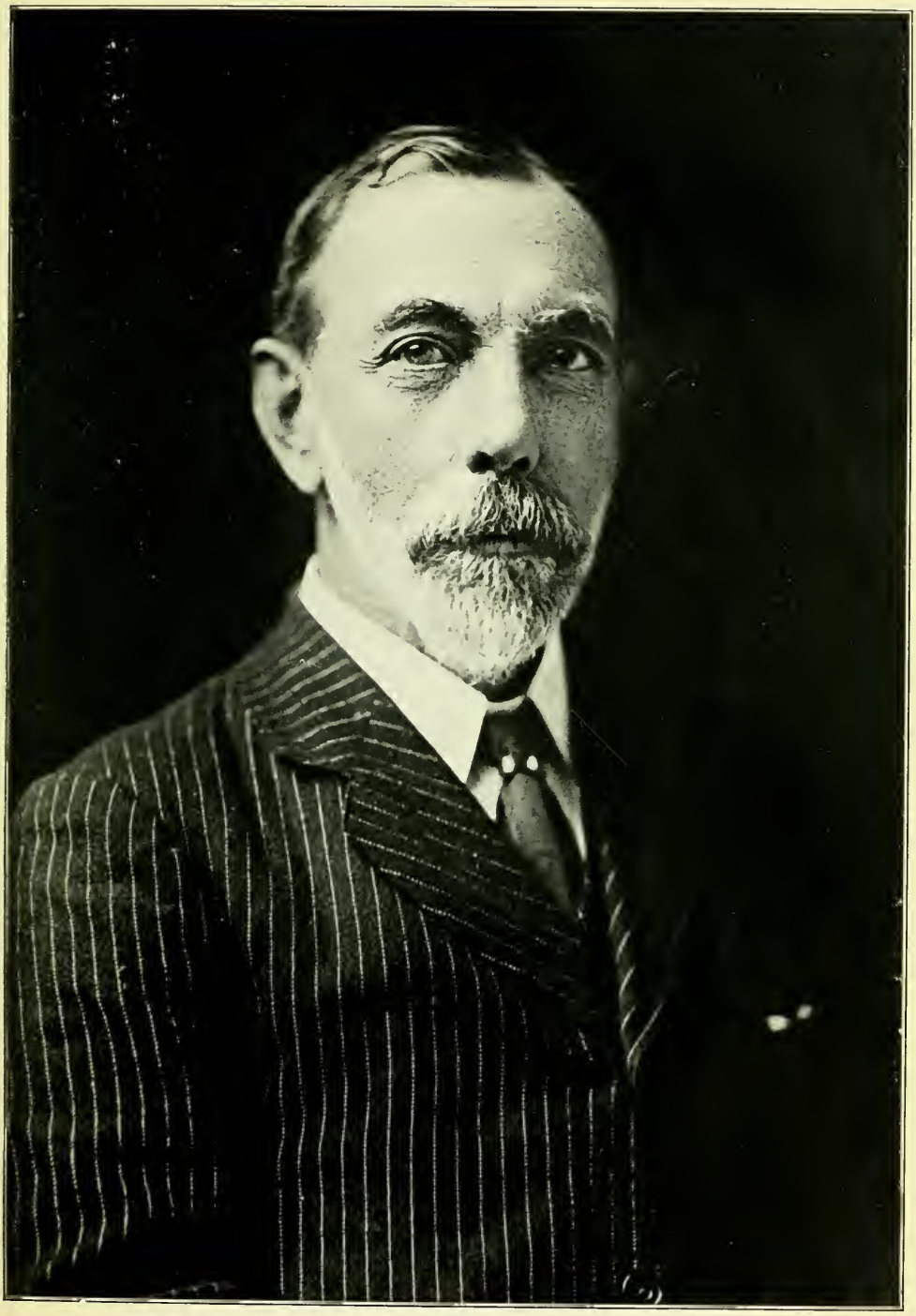
At the Symposium several valuable Papers were read, which I think deserved more attention than they received at the time. One was "The Training and Work of the Chemical Engineer," by Sir George Beilby, F.R.S., another "The Training of the Chemical Student for work in the Factory," by my friend Professor F. G. Donnan, F.R.S. Perhaps your Society might like to have these papers discussed at one of its meetings. I am sure the Faraday Society would be glad to give the necessary permission.

I am pleased to note that Professor Wilsmore has studied this Symposium and, in the Presidential Address to which I have already referred, recommends its examination.

THE RAMSAY MEMORIAL

It may be interesting in an audience of Chemists to refer to a Fund, with the management of which I am concerned as one of the Trustees, that is, the Ramsay Memorial Fund, founded in memory of one of the greatest Chemists in the World, British born and bred too. For thirty-five years Sir William Ramsay occupied a foremost place in the ranks of Scientific Investigators, and his discoveries in the realm of Chemical Science earned for him a world-wide reputation; his portrait is shown in Plate 9. Sir William spent no less than twenty-six years of his professional career at the University College, London.

The Memorial Fund raised in his memory now amounts to over £53,000, divided into (*a*) the provision of £25,000 for the foundation of a Laboratory of Chemical Engineering in connection with the University College, London; (*b*) the foundation of Ramsay Memorial Fellowships for the advancement of



SIR WILLIAM RAMSAY, F.R.S.

Research in Chemical Science. Each Fellowship is worth about £250 per annum, with a grant attached of £50 towards expenses, and is tenable for one year in any University of the United Kingdom. The Fellowship may be renewed for a further year if the Fellow is considered satisfactory and desires an extension of the Fellowship.

There are at present two Fellowships held in the United Kingdom. The first British Fellow, Mr. William Davies, was elected in July, 1920, and was re-elected for a second year in July, 1921. The second Fellow, Mr. Alan Ernest Mitchell, was also elected on this date. There is a third Ramsay Fellowship in the United Kingdom, limited to candidates from Glasgow. This Fellowship is at present vacant. It is to be hoped that some of our Sheffield Chemists may be able to obtain one or more of these Fellowships, founded in memory of this great Englishman.

In addition to the above, Ramsay Fellowships have been founded by the Governments of Denmark (where Miss Agnes Petersen, Assistant in the Physical Chemical Polytechnic Laboratories of Copenhagen, has been selected), Greece, Holland, Italy, Japan, Norway, Spain, Sweden, and Switzerland. In the case of France, the Government has not yet taken action, but a special Fund has been raised in France for the contribution of a Fellowship. One British Dominion, namely, Canada, has also founded a Fellowship, through the Honorary Advisory Council for Scientific and Industrial Research, Ottawa.

During the Session 1920-21 the Fellows from Greece, Japan, Switzerland, and Canada were at work in the various Universities of the United Kingdom, and it is to be hoped that at the commencement of the Session 1921-22 the remaining Fellows will have arrived in this country.

The subscriptions to the Fund from the leading Foreign Countries have been : Switzerland £911, America £4,076, Japan £500, Italy £400, India £611, Denmark £198, Norway £186, Chile £128, Greece £259, Holland £2,005, and France 108,000 francs.

As regards the Laboratory of Chemical Engineering, the actual arrangements for the erection of this Laboratory have not yet been settled, but it is hoped that progress will be made in this matter in the course of the next few months.

The Executive Committee, through the University College Committee, have been in communication with the Senate of the University of London. They have made a contingent offer of a sum of not less than £25,000 to the University of London for this

purpose, subject to the University finding itself in a position to provide a suitable site for the Laboratory.

The Senate have gratefully accepted the contingent offer, and have intimated that they are prepared to provide a suitable site on condition that the remainder of the sum necessary for the erection, equipment, and maintenance of the Laboratory be available from the Ramsay Memorial Fund or from other sources.

In addition to the above, arrangements are now being made for a tablet in memory of Sir William Ramsay to be placed in Westminster Abbey. The Artist, who has almost completed the work, is Mr. Charles Hartwell, A.R.A.

The Committee has been much indebted to the work of its energetic Secretary, Dr. Walter W. Seton, M.A.

SIR JAMES DEWAR

I should like this evening to pay tribute to one of our greatest living and British Chemists, Sir James Dewar, whose portrait is shown in Plate 10, specially as this year is a notable landmark in his life, both in view of the fact that he is now in his eightieth year, and that he and his wife celebrate their Golden Wedding. Might I suggest that, as Sir James has laboured long and successfully on behalf of the Science of Chemistry, our Society should send him a letter of good wishes.

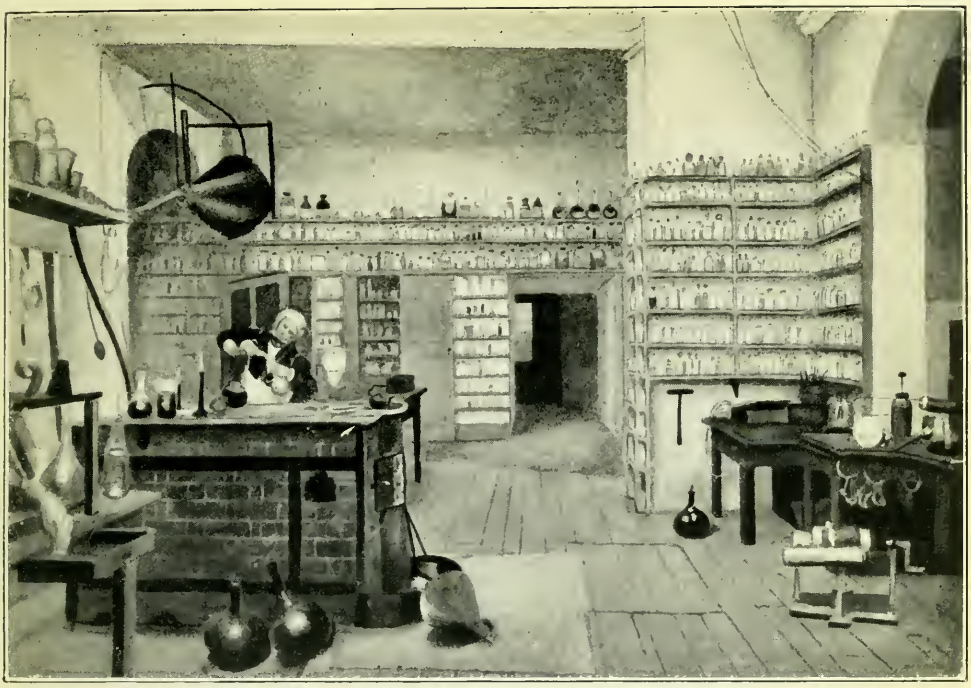
Dewar, early in his life, was attracted to the study of the Science of Chemistry under Kekule at Ghent. His great work in both High and Low Temperature Research, and along with Abel in the Chemistry of High Explosives, as well as many other important advances in Chemistry, have made his name renowned throughout the World. His work for a period of many years at the Royal Institution, the centre of light and leading in Scientific Lectures, has been invaluable to our nation. He has freely given his great intellectual powers, time, and money to encourage by means of lectures this rational and most interesting way of imparting knowledge of Scientific subjects.

A great Chemist, Lyon Playfair, claims to have discovered Dewar and Frankland, whom he termed "two very active Radicals," both in the Chemical and the other sense.

In a speech given at the Annual Dinner of the Chemical Society in March of this year, Professor H. B. Dixon pointed out that even Hades had been made endurable, for the new-comer

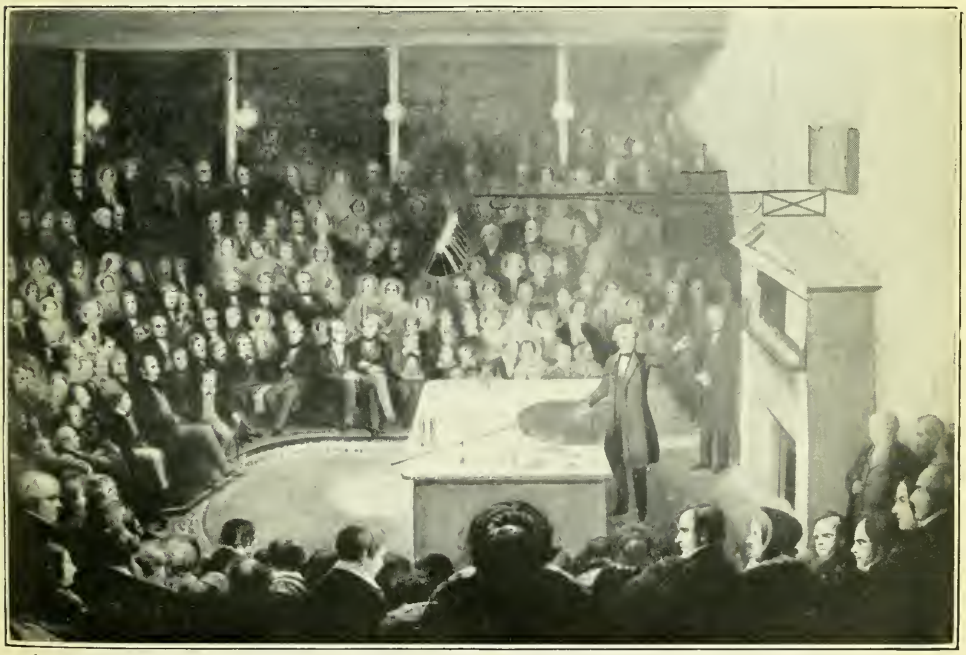
SIR JAMES DEWAR, F.R.S.,
in his Laboratory.

PLATE 11.



The Royal Institution Laboratory, showing Faraday at work.

PLATE 12.



Faraday lecturing before H.R H. the Prince Consort, December 27th, 1855.

on reaching its portals was astonished to find a pleasant sub-tropical climate, as Sir James had instituted there his liquid air plant, and there was also a choice of well-cooled drinks in Dewar silvered vacuum flasks. As Dixon says, even if Dewar has not reached the absolute zero, he has himself hewn the only way by which the Nadir of Temperature can be reached, and he has approached it near enough to point out the chief landmarks of that region where Chemical Action and Electrical Resistance disappear. Such a record is one with which the successor of Davy and Faraday may rest well satisfied.

It may be of interest to refer to this historic building where Dewar works, the Royal Institution, Albemarle Street, London, founded by Rumford in 1799, where some of our greatest men have for very little stipend given their life's work to Scientific education, and where the permanent Lecturers have been not only of national but international importance. I refer to Thomas Young, Humphry Davy, Faraday, Brande, Tyndall, Frankland, Odling, John Hall, Gladstone, Crookes, Rayleigh, Thomson, down to Dewar himself. Plate 11 shows the Royal Institution Laboratory with Faraday at work; and Plate 12, Faraday lecturing before H.R.H. the Prince Consort, December 27th, 1855.

To give some idea of the work carried on at the Royal Institution, I may mention that last Session no less than 63 separate Lectures were presented, many of them by the master minds of the Scientists of to-day.

THE INFLUENCE OF CHEMISTRY IN THE WAR

Professor Wilsmore, in the able Presidential Address I have mentioned, stated that on the whole the effect of the War on the position of Chemistry and Chemists has been favourable. It has provided an object lesson on the national importance of Chemistry which the man in the street cannot afford to ignore.

I am delighted to see that Professor Wilsmore, whilst critically examining the position of Scientific matters within the British Empire, is of the opinion that in one of the most important branches of Applied Chemistry, the Steel Industry, a line of work in which our City is so much interested, intensified Research and Scientific Control has been greatly encouraged, the result being that when the crisis came the Industry was able to respond to the enormous and varied demands made upon it. He is quite

correct, and we in Sheffield can be proud of the fact. I think we can say this was one of the principles upon which the work of the Sheffield University was founded.

GERMAN CHEMISTS

We have had so many brilliant Chemists in our national life, that I have never understood why the Teutonic Chemist has been held up to such glory. Robert Boyle, termed the Father of Modern Chemistry, a Fellow of the Royal Society, and whose portrait is shown in Plate 13 (Frontispiece), has an imperishable memory. Then we have Roger Bacon, Black, Cavendish, Priestley, Davy, Wollaston, Faraday, Playfair, Roscoe, Graham, Abel, Crookes, Ramsay, Dobbie, Soddy, Bragg, Rutherford, Perkin, Thorpe, Armstrong, Abney, Jackson, Tilden, Dewar, Beilby, Meldola, Dixon, Scott, Pope.

No other nationality can outvie such a list, and certainly not Germany, who must recognise that full social intercourse with the nations of the World cannot take place until she thoroughly repents from past errors and honestly mends her ways.

Speaking personally of the German nation, I have never felt alarmed about their competition, whether mental or physical. It is true their industry and application cover a multitude of their other sins, but I see no reason to think they are superior men; quite the contrary.

Whilst speaking thus of a beaten foe, we must nevertheless admit that in the past they have played a useful part in Chemical Science. It is not, however, for me to discuss this at length to-night; I am, as you know, dealing chiefly with that branch of Chemistry which has its application to Metallurgy.

In the valuable article which appeared in *Chemical and Metallurgical Engineering* for August, entitled "Chemical Supremacy with the English-speaking people," the happy announcement is made, with which I quite agree, and I believe all of you will do so, that Chemical supremacy rests with the English-speaking people. The early history of Chemistry, in fact in the recent past too, abounds in names of English rather than Teutonic investigators.

As the article I have just mentioned points out, the Teuton, because of his diligence and industry, has been given more

credit than he deserves as regards fundamental discoveries and developments. We have only to call to mind such names as Ramsay, one of the greatest Chemists, and Perkin, who undoubtedly originated the great advance in the World's knowledge of Dyes.

In the past the German played his cards so well that he earned a reputation which he really did not deserve. As the article in question says, he capitalised on this reputation through his literature and Universities until it required a great War to disillusion the rest of the World, and to awaken a sense of equality and independence in Science, particularly Chemistry.

Signs are not lacking that the old order changeth, one being that we are no longer going to be dependent on German literature for knowledge of what is being done in the World of Chemistry. It had become the fashion to accept German as the language of international Chemistry much as French has served in international Diplomacy. There is no reason why the present movement should not increase more and more, so that English merits the distinction of being the international language of Chemistry.

In saying this, it is not meant to imply that Germany has not done and will not do her share in helping to advance knowledge. Nevertheless, whilst Germany has performed useful work in the past, there is no reason why German Chemistry should be allowed World-wide domination, as was the object of her pre-War policy.

That I am not alone in this view is shown by the fact that one of our leading chemists, Sir William A. Tilden, states that whilst it is not easy to estimate the relative positions of the Nations by mere enumeration of the names of their Chemists, as they are of such very different importance and size, nevertheless the Germans have in the past laid claim to more than their due. At the same time no other people have any name to compare with the names of Baeyer and Emil Fischer. Sir William also points out the magnificent record of work done by this country duly recorded in the proceedings of the Chemical Society, which he considers to be of higher quality than that of the corresponding German Association.

I well remember the help I received in my earlier days from the useful books of Fresenius on Chemistry. I will also mention my friendship of long standing with a famous German Chemist; I refer to Professor A. Ledebur, of the Freiburg School of Mines and Chemistry, of which he was the head for so many years and from which many useful Chemists have been turned out.

Ledebur, whose portrait is shown in Plate 14, represented the type of good German which used to exist. A picture of Ledebur's Laboratory is shown in Plate 15.

I corresponded with Ledebur for many years, in fact, up to his death in 1906, at the age of 69, and always found his views upon the perplexing question of the nature of Carbon compounds in Iron and Steel sound and most useful. His excellent Papers to the Iron and Steel Institute were helpful to all of us. I am glad to say Ledebur's work helped to keep my mind, and no doubt that of others, clear from the taint of the allotropic heresy. I refer to that portion which was presented by some amongst us, but which has been rejected, thanks largely to the great opposition of Sheffield and its Metallurgists.

Ledebur was an honest seeker after the truth, and I should like to throw upon the screen to-night a few words which I came across in a little book entitled "Adolf Ledebur, his Life and Work," which was sent to me after his death. These words about Ledebur and his life may well be taken to heart by all of us: "A wide acquaintance and a broad life; Long years of honest endeavour; Always investigating and always well-founded; Never close in thought but always plain and open; Preserving the truth of the old; Receiving the new in a friendly spirit; A noble mind and a pure aim; Death comes well to such a man."

Section V

THE INDEBTEDNESS OF THE METALLURGIST TO SCIENCE

On looking over my former Addresses, in the one I delivered as President of the Iron and Steel Institute in 1905, I called special attention to the Metallurgist's indebtedness to the Man of Science.

I pointed out the remarkable discovery of Recalescence by that able Scientist, my friend of long standing, Professor, now Sir William, Barrett, from which such important results have accrued for the benefit of the Science of Metallurgy, and which shows how a man of Pure Science, although himself not a Metallurgist, could render the greatest service to our own Branch of Science, Metallurgy. The accurate determination of High Temperatures, Recalescence and other critical points, have all been chiefly due to the Man of Science, and not to the Industrial Worker. This is but another proof of how necessary it is that the two factors of progress, Science and Practice, should go, as far as practicable, hand in hand, for, as exact laws are discovered by means of scientific research, so does the quality of our material knowledge improve, and the practical man is then able to apply the knowledge so gained.

Faraday, with his keen mental vision, saw the great importance of scientific investigation in Metallurgy when in 1822 he produced those many remarkable alloy steels in the Sheffield works of Sanderson to which I have referred in several of my previous Papers and Addresses.

Metallurgists, therefore, are specially grateful to the band of workers in pure Science, who, in this Country, America, and on the Continent—I refer amongst others to such men as Gore, Barrett, Hopkinson, father and son, Osmond, Roberts-Austen, Callendar, le Chatelier and Sauveur—thought that the study of Metallurgy was worthy of recognition. It is largely owing to their efforts that we have been able to progress so rapidly, and it is due to them that Metallurgy no longer feels its way haltingly along the former dark paths of empiricism, but now advances with swift and certain steps, guided by the pure light of Science. In fact, Metallurgy has become a part of Science.

The Astronomer may investigate the Worlds around us, the Geologist the World at our feet, the Engineer, the Electrician,

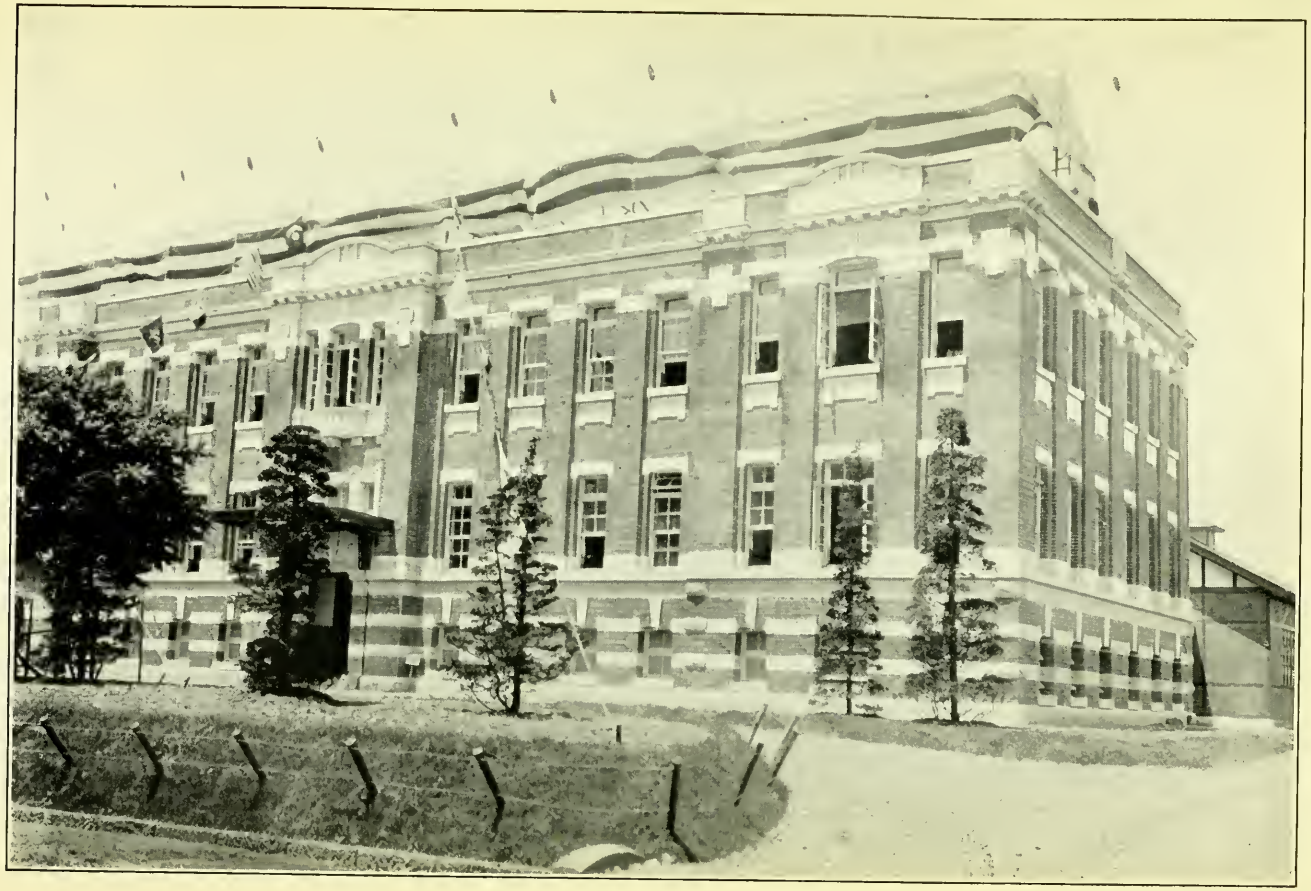
the Chemist, the Physicist, and the Mathematician each study phenomena of the greatest intricacy; but the Metallurgist, including the Metallurgical Chemist, has to solve problems not less difficult nor less important; and he can well claim that his profession entitles him to take a place in the council of the international University of Science.

Such were the words I wrote in 1905. Since then, as you are well aware, we have succeeded in establishing a centre of learning in our midst, the University of Sheffield, in which Metallurgy is recognised as a Branch of Science and granted its own Faculty. Its first Dean was Professor Arnold, who presided over it with so much ability. The present Dean is my friend, Professor C. H. Desch, and I am sure we all wish him every success in this important position. He has already shown great ability and breadth of vision, and I know he will continue the good work and maintain the proud position of our Faculty of Metallurgy.

If our Society would do me the favour, I wish, as a little memento of this evening, a letter of good wishes could be sent to our friend of long standing, Professor Arnold, saying that although he is no longer in our midst, we have not forgotten the excellent work he did for our University and for the good old City of Sheffield.

JAPANESE RESEARCH INSTITUTE FOR IRON AND STEEL

As showing that even in the Far East attention is being paid to this important subject of Research, those present this evening may like to see a picture on the screen of the new Japanese Iron and Steel Research Institute (Plate 16), the Opening Ceremony of which took place on July 9th and 10th of this year at Sendai, Japan. I have just heard from Captain S. Kobayashi, Naval Attaché in London to the Imperial Japanese Navy, and Admiral T. Noda, that the generous Donor of this Building was Baron K. Sumitomo, of Osaka, Japan. The Institute is stated to have cost about one and a half million yen. This building is devoted solely to the investigation of Iron and Steel. I should imagine it is the only one exactly of its kind in the World that is solely devoted to the Metallurgy of Iron and Steel. Professor Honda wrote me last year that the Institute



The Japanese Research Institute.

contains about 1,800 square metres in area of rooms, and gives accommodation for two Professors, five Assistant Professors, and ten Assistants.

This development in the Far East conveys a lesson to us which I hope will be taken to heart, and shows that our Japanese Allies intend to encourage and develop the Science of Metallurgy in their Country.

I am sure that the Faculty of Metallurgy in the Sheffield University, also our two local Societies, would be glad to join in sending hearty greetings from those studying the Science of Metallurgy here, and in wishing the new Institute every success. It would be a friendly act to send such a complimentary letter, and I suggest this for your consideration.

Professor K. Honda, of the Tohoku University, is in charge of the Institute. He and his Assistants have done excellent work and contributed a number of Papers to our Iron and Steel Institute, most of these being of considerable interest. Many of these papers formerly went to the Continent, in fact to Germany, but Professor Honda and others now send their contributions to English-speaking bodies for publication, chiefly the Iron and Steel Institute.

In view of the excellent research work carried out by Professor Honda, on May 4th, 1922, the Council of the Iron and Steel Institute awarded him the Bessemer Gold Medal for that year.

Mr. G. Spiller, in his Paper on Darwinism and Sociology points out that the marvellous changes which Japan has undergone during the last two generations have startled the West. From an excessively peace-loving population it has transformed itself into a warrior race, whilst as if by a magic wand it has also developed its intellectual side to the extent of making scientific contributions of no mean order.

Professor Wilsmore in his able address previously referred to, calls attention to the fact that there is good reason to believe that amongst the Asiatic peoples men not inferior in ability may be found, who, given suitable environment, may produce similar results to those races showing the present cultural ascendancy.

METALLURGICAL LITERATURE

THE quality of the literature of a particular branch of Science generally shows the relative position it occupies in the World, and this is well illustrated by the Science of Metallurgy.

I have a collection of some three hundred books on Metallurgy, chiefly old, dating from about A.D. 1400 down to the present time. Some years ago I had prepared a chronological catalogue of this collection, and although not many of these are now left, I shall always be glad to spare a copy to one or two of those specially interested. I add the following list of the names of the writers and the dates of publication of the older books, which may be useful to those interested in this particular lore, though it does not pretend to include the names of modern contributors, that is, later than about 1870, as these would be far too numerous. To show the wonderful progress made in the Science, it can safely be said that hardly any of the books published before 1870 would be of the slightest value to-day, so rapid has been the advance and gain in our knowledge. These have been literally phenomenal, perhaps more so than in any other branch of Science.

The following are the names of the chief writers on Metallurgy between 1546 and 1880, that is, a period of over 300 years:

Agricola	1546	Mushet, David	1840
Dud Dudley	1665	Faraday	1842
Sir J. Pettus	1683	Heath	1856
Reaumur	1722	Percy	1861
Swedenborg	1734	Holley	1865
Jars	1774	Whitworth	1866
Bergmann	1778	Kohn	1869
Rinman	1782	Osborn	1869
Cronstedt	1788	Crookes	1870
Berthollet	1789	Rohrig	1870
Vauquelin	1808	Gruner	1872
Karsten	1824	Greenwood	1874
Berzelius	1833	Barba	1875
Berthier	1834	Ledebur	1877
Jeans	1880		

It will be seen that even as late as 1870, only fifty years ago, such literature was meagre indeed. A student of to-day would

not write much of the material then put forward for consideration. We Metallurgists simply did not know and had but little Scientific guidance of any kind. It was the day of rule of thumb. Beyond Percy's admirable Treatises and one or two others, books of value on Ferrous Metallurgy were few and far between, neither were there any technical Societies in this Country or elsewhere dealing with this Branch of Science until 1869, when the Iron and Steel Institute was founded.

Metallurgy has now a wide range of Scientific Literature dealing with the Ferrous and Non-Ferrous sides respectively, all helping on our knowledge.

There are, too, the British Iron and Steel Institute, with nearly two thousand Members, the American Iron and Steel Institute, the American Institute of Mining and Metallurgical Engineers, with probably ten thousand Members, the British and American Institutes of Metals, and other Anglo-Saxon bodies dealing with Metallurgy, to say nothing of smaller Societies here, in France, Belgium, Italy, Sweden, Germany, Austria, Russia and elsewhere. There are, therefore, to-day tens of thousands of Members of the Profession devoting attention to Scientific and Practical Metallurgy, and all this has been done in the short space of time represented by but half a Century. The future march of Civilisation largely depends upon the Scientific understanding and handling of the great and wonderful metal "Ferrum," with which I have worked all my life, and the control of its qualities. I can justly claim for it pre-eminence amongst the metals as regards its thousand and one applications. Take away Iron, and it must be admitted that we should go back to the dark ages.

Section VII

METALLURGY AND POETRY

In addition to Metallurgy being Scientific, we can claim that it has its poetical side too.

Poetry has been defined as the Art which has for its object the creation of intellectual pleasures by means of imaginative and passionate language. Coleridge has said that the proper and immediate object of Science is the acquirement or communication of truth, and that the proper and immediate object of poetry is the communication of immediate pleasure. The Tuneful Nine, as our Muses are sometimes described, have brought Metallurgy under their spell too.

In the works of our great poet Shakespeare there are abundant Metallurgical references, and as one of the Governors of the Shakespeare Memorial Theatre, Library and Museum—probably I am the only one interested in Metallurgy—during a recent visit to Stratford I spent some time at the Museum, of which Mr. Ernest Lodge is now the Curator. I wished to ascertain whether Shakespeare possessed any special knowledge of Metallurgical lore such as it was in those days. Several references are being followed up, and I hope with the kind help of Sir Sidney Lee, who has interested himself in the matter, to be able to say something in this direction before long.

It appears that in Shakespeare's Will there was a mysterious Overseer and Legatee, John Russell, who Sir Sidney thought might be identified as one of the leading Metallurgists of that day, and who was on terms of intimacy with Sir Francis Bacon. I hope to be able to obtain some information on this point.

I do not know whether any of those present have seen the fascinating Latin Poem entitled "Ferrum," composed in 1717 by Le Prêtre Xavier de la Santé, a Jesuit Professor of Rhetoric at the College of Louis-le-Grand, Paris. A copy of this, now in my Library, together with his own rendering in French, "Le Fer," was sent to me in 1906 by the late Professor Floris Osmond.

This is a fine poetical conception regarding the metal Iron—Professor Henry M. Howe wrote a few lines of introduction to the translation, saying :—"I charge my students to read poetry, hear good music, see works of art; so will they become better Metallurgists."

On the first page of my copy are the following words written by Professor Osmond himself: "This little book, my dear Monsieur Hadfield, of which I ask your acceptance, represents quite an old allotropic theory, with which probably you are not acquainted, but which is more pleasing than mine. I hope that you will find in it something which will interest and attract you. Believe me to remain always, yours faithfully and devotedly, F. Osmond."

The contribution is of high poetical merit, and is worth perusal. This evening, however, I only propose to deal with the last few pages of the poet's fine frenzy, the conception in which, to express it in prose, runs somewhat as follows:

"There were two brothers, twins, Sidère and Sidérite, who lived in the country of the Chalybes in Magnesia, from which, by the way, some believe we obtained the word Manganese. The original Chalybeans were renowned ironworkers, and were mentioned by Herodotus in the fifth century B.C. The *locus* was Armenia, on the shore of the Black Sea. The two brothers mentioned were deeply attached to each other, like David and Jonathan, and their affection was 'passing the love of woman.'

"It happened that Sidérite, one beautiful starlit night, was greatly attracted by one particular star shining in the firmament. It appears that this star represented a goddess who had been a nymph of such beauty that she had been made a star by Jupiter himself, and placed as one of those forming the constellation of what we now call the Great Bear. Being of the feminine gender, therefore always curious and on the look-out, she perceived Sidérite from her starry heights and immediately fell in love with him.

"She at once descended to this mundane sphere, and expressed to Sidérite her affection and that she was ready to marry him.

"Sidérite, however, whilst admitting his admiration for her, pointed out that he, a human being, could not and should not marry a goddess, and he spurned her advances. Moreover, he would not on any account abandon his love for his brother, Sidère. This made the goddess very furious, but neither her expostulations nor her beauty caused Sidérite to depart from his decision.

"The goddess in her wrath then turned him into a pillar of Stone, but before the transformation was quite complete the brother, Sidère, appeared on the scene. When discovering the

fate of his brother, Sidérite, he begged that he might share this. The goddess agreed to allow him to share his brother's fate, but with this difference, that he, Sidère, was turned into a pillar of Iron. And there to-day, in the country of the Chalybes, this fine poetical fantasy can be proved to be quite true—that is, if you can find the exact spot—for, side by side will be found two pillars, one of Stone and the other of the metal Iron."

Section VIII

GENERAL REFERENCE TO THE LECTURER'S RESEARCH WORK

With a view to encourage the younger men in our midst, I was particularly asked to say something this evening about my own Research Work, how I commenced, what I did, and so on. This would take a long time to narrate in full.

In a general way I may say that my Research work has extended over thirty-nine years. I find that the first entry in my Experimental Note-book is dated September 7th, 1882. Much of the various work carried out has been described in about 130 Papers to Scientific and Technical Societies, as well as in a large number of Articles to the Scientific and Technical Press.

During the long period mentioned, it has given me great pleasure and satisfaction, not only to carry out my own Research work, but also to be able to help numerous Scientific and Technical Investigators with advice and assistance. Still further, to furnish many thousands of specimens of various Alloys of Iron and Steel to Investigators all over the World to enable them to carry out research and experimental work.

It may be interesting to add that during this time I have been in active co-operation and touch with about 250 Fellow Workers and Investigators. It would not be possible to spare space to give the names of all these, but amongst them are many who have been famous in their day and generation, and who have helped on the good work of Research and Progress in this country, the United States, France, Belgium, Sweden, Germany, Russia, Italy, Holland, Spain, Switzerland, and Japan.

I have contributed Papers to the Royal Society, the Royal Society of Dublin, the Institution of Civil Engineers, the Iron and Steel Institute, the Institution of Mechanical Engineers, the Institution of Electrical Engineers, the British Association, the Faraday Society, the Society of British Gas Industries, the British Commercial Gas Association, the American Institute of Mining and Metallurgical Engineers, the Franklin Institute, the Société des Electriciens, and other scientific and technical bodies.

A well-known Scientific Authority, Professor Farmer, F.R.S., said not long ago that when judging the value and quality of Research work, it should be borne in mind that every credit

should be given not only for work done personally by the Investigator, but also for what he inspires in others. I venture to hope that my Research work has resulted in the accomplishment of both these objects.

In this respect, when speaking of my Research work, my friend the late Professor Floris Osmond, the eminent French Metallurgist and Bessemer Gold Medallist of the Iron and Steel Institute in 1906, whose name is a household word in the Science of Metallurgy (a facsimile of whose first letter to me, dated October 22nd, 1889, is shown in Plate 17), made the following statement during the discussion of my Paper on "Alloys of Iron and Tungsten," read before the Iron and Steel Institute in 1903. I also give his remarks in order to show why my Discovery and Invention of the Alloy Steel known as Manganese Steel, practically the first development in a new direction, was of such an important character, quite apart from the intrinsic value of the material itself. Besides, the Research work carried out on Manganese Steel led to the introduction and examination of other new materials, and also directly and indirectly helped on the solution of many Metallurgical problems.

Professor Osmond said: "The series of the Hadfield Alloys had been prepared with a degree of Technical skill which upset many falsely conceived ideas, resulting from imperfect preparation or from faulty manipulation. Hadfield's method was a truly Scientific one, by means of which all the independent variables which could be disposed of were eliminated. With the materials for investigation thus prepared, which for a long time had been unrivalled, the results obtained were at once clear, coherent, and definite. Moreover, Hadfield had not only made the best personal use of this wealth of material, but with never failing generosity of which the writer had many times availed himself, he had placed it at the disposal of those Inventors who were desirous of subjecting it to their methods and using it for their Researches. Consequently, the useful results had rapidly gone on increasing, and from the accumulation of these the general laws had been evolved which formed the main object of all Research."

Again, when speaking of the transformations of Iron and Steel, Osmond made the following important pronouncement, which is really a Metallurgical landmark: "Now, according as, with a given addition of one or several foreign bodies, and under fixed conditions of heating and cooling, the transformations were maintained above 400°C. approximately, or were

Paris le 2/10/87

Monsieur,

J'ai lu avec beaucoup de plaisir le mémoire que vous avez présenté au dernier meeting de l'Iron and Steel Institute. Je me permets de vous adresser, par la même courrier, un exemplaire d'un travail sur les transformations du fer et du carbone dans les fers et les aciers. Je crois qu'il serait très intéressant d'étudier, par la même méthode que j'ai employée pour le carbone et le manganèse la collection, unique au monde, d'aciers silicieux que vous avez préparés. Je vous donc vous demander, (ce texte pour cela n'est pas indiscret de la part d'un étranger qui n'a pas l'avantage de vous avoir été présenté), s'il vous conviendrait de mettre à ma disposition de petits échantillons de ces aciers. Au regard de quelle manière scientifique vous prétendez la métallurgie, j'ai pensé que cette demande avait des chances pour être bien accueillie par vous. Si vous voulez bien me faire une réponse favorable, je vous indiquerai les formes et dimensions qui seraient les plus convenables pour un essai.

Veuillez agréer, Monsieur, l'assurance de mes sentiments les plus distingués,

F. Osmond

83, Boulevard de Courcelles, Paris

lowered so as to occur between 400°C. and the ordinary temperature, or were pushed down to a point below the ordinary temperature, there would be produced three essential types of iron, not taking account of the intermediary types which connected them. These three types would correspond respectively to the complete transformations, to the incomplete transformations, and to no transformations at all. The first type was soft iron. The second corresponded to hard quenched steel and its kindred alloys. The third corresponded to non-magnetic steels, which are malleable and at the same time very difficult to work by forging. The two first had been familiar since the dawn of history, the third was due to the discoveries of Hadfield. Considered from this point of view, the discovery of Manganese Steel was not, therefore, a discovery only of a new Alloy, curious and yet useful, but it ranked as a discovery equal in importance only to that of the effect of quenching, that is, the hardening of Steel by quenching, in the history of the Metallurgy of Iron, the only one of the same order which it had been reserved for our age to make."

On reflection it will be seen that this statement is most important and quite true. I have therefore given Osmond's remarks in full, as quite apart from my personal connection with them, they are useful for historical reference, and should be a stimulation to our rising generation of Metallurgists.

It will thus be seen that the Discovery and Invention of the extraordinary material and Alloy, Manganese Steel, was not only of great value in itself, but quickly led the way to a large number of important Metallurgical developments. It was the first voyage of the ship of modern Metallurgy into the then practically unknown sea of "Ferrous Alloys," in fact to slightly modify the reference by Coleridge in his "Ancient Mariner," a quotation made by my friend Arnold in another communication, "It was the first which ever burst into that unknown sea."

This Discovery opened up a new era in the Science of Metallurgy. It can therefore be easily understood how, after this important advance in knowledge, there quickly followed the many further and wonderful advances of all kinds of Steel Alloys without which, be it remembered, the World could not exist to-day, that is on its present lines. Let us take but one example. Remove Alloy Steels and the high efficiency motor-car of to-day, one of our modern wonders, could not be produced. Not long ago I left my house near Sheffield at 8.30 a.m. and got out of my car in Pall Mall at 1.40 p.m., a distance of 164 miles. I need

hardly say that in doing so we never interfered with the comfort of or inconvenienced anyone upon the road. The construction of a motor-car engine with its various steel parts and driving gear, capable of accomplishing such a speedy journey, has only been made possible by the production of Alloy Steel. Manganese Steel, although not suitable for this purpose, was practically the first Alloy Steel which led the way into this new field. If Alloy Steels and Heat Treatment were taken out of the World, many of our modern advances would collapse.

In Manganese Steel an Iron Alloy was obtained which is practically non-magnetic, a quality which made it of the highest service in the War; on the other hand, another of my Alloys, Silicon Steel, offers a remarkable antithesis to Manganese Steel, being found under low magnetising forces to be in some ways really more magnetic than Iron itself.

Thus it will be seen that the "unknown sea" to which I have referred then quickly became open to many other Investigators, amongst the earliest being Riley, Hall, and Arnold, of England, Brustlein, Osmond, and Guillet, of France, Metcalf in America, and eventually a host of others in various countries. Many of the later Investigators have often been kind enough to tell me that they have been inspired by my first Experiments, and followed in the path pointed out by me and the other early pioneers to whom I have referred.

I followed up with many other Investigations, including Nickel Steel, Chromium Steel, Aluminium Steel and other combinations.

To outsiders it may seem comparatively simple to produce a new Steel Alloy; they may think it is merely a matter of mixtures, but it is much more than this. Often, too, the solution of matters which apparently seem simple, proves to be the most difficult of all Researches.

As showing the peculiar nature of Invention and how this comes about, may I refer to an important and epoch-making one, that of the great Scientist, Marconi, in his Invention of Wireless Telegraphy. It has been asked by some, what did he do? This is described in a most interesting Paper on "Wonderful Wireless Waves," by an American, Dr. A. W. Kinnan, which appeared in the *Journal of the Patent Office Society*, Washington, D.C., in January last. The writer points out that all the materials upon which Marconi was to build the Invention had been created. The Oscillator, including the Key, the Interrupter, the Transformer, the Spark-Gap Apparatus and the Radiating Plate, the

Receiver, including the Receiving Plate, the Coherer, the Tapper, the Galvanometer, had all been created and their use indicated. Other actors were hard upon him, ready to step upon the stage. Clerk-Maxwell and Hertz had pointed out the way; Branley, Lodge, and Popoff had travelled in the direction thus indicated to them, and were in 1896-7 standing in the wings of the stage. But even so, they never entered, and the light never fell upon them until Marconi had given Commercial Telegraphy by Hertzian Waves to the World. It was a noble gift, and the reward and glory are justly due to this remarkable Italian, whom we are proud to have in our midst. Viewed in the light of what is now known, Marconi would appear to have made but little change in known apparatus in order to adapt it for signalling at greater distances. But one must remember that known apparatus would not work for the purpose desired, and there was no one to explain why. He had to modify, adjust and change in conformity with what long, laborious, and often confusing experiments taught him. Work of this character often requires a keenness of mind and a quickness of perception greater than required to create some device *de novo*. It is not necessary for me to go into the details of the Marconi Invention, they do not concern us at the moment, though it may be added that he succeeded in 1896 in sending messages 100 yards; in May, 1897, to nearly nine miles; in July, 1897, to twelve miles; in July, 1898, to twenty miles, and in 1901 across the Atlantic Ocean.

In the same way, in 1882, there were ready to my hand certain combinations, or raw Alloys, but I think I may say without presumption that no one had fully entered that "unknown sea" of Alloy Steels at the date I discovered Manganese Steel. The extraordinary results obtained from this Steel and its examination led the way to entirely new ideas regarding combinations of Iron with other elements.

Beyond small percentages of elements other than Carbon added to Iron, very little was known about Alloy Steels, the chief one of importance being the self-hardening Tool Steel produced by Mushet in comparatively small quantities and having a limited use.

When speaking of Research Work I wish to express this evening my great thanks to the many willing assistants on my own staff who have aided me for many years. They have rendered not help merely, but it is no exaggeration to say devotion of high order.

It is almost invidious to mention names, but I should specially like to refer to some of them. Amongst those, alas, gone before, are the names of Mr. E. Wheatcroft, an able Chemist of earlier days, also Mr. John Mallaband; and of those who are happily still with us, the names of Messrs. A. M. Jack, P. B. Brown, Major A. B. H. Clerke, J. P. Crosbie, I. B. Milne, W. J. Dawson, W. E. Parker, T. G. Elliot, S. A. Main, E. Ott, G. B. Willey, L. J. Swift, T. H. Burnham, F. Ellison, A. Stevenson, E. Rodgers, W. Cross, and others.

On the clerical side, including the recording of experiments and classifying them, that is, general secretarial work, not an unimportant part of Research, I have been indebted for help, cheerfully rendered often under difficult circumstances, to Messrs. Hemsoll, Mortimer, Heeley, Hallatt, Rowland, and many others who later came to me. I should like to add that Mr. Hemsoll assisted me in acquiring a fair knowledge of Shorthand, which in my busy life I have found simply invaluable; in fact, it would have been impossible to get through the large amount of work I have done without the aid of Shorthand, and may I here bear a testimony to the work of that great man Sir Isaac Pitman, who invented the wonderful system of rapidly putting down on paper not words merely, but thoughts.

Section IX

MANGANESE STEEL

A Brief Reference to its Invention and Application.

As it is quite impossible in the short time and space at my disposal to do justice adequately to the subject of the important product Manganese Steel and its Invention, I shall not attempt to do this either as regards its history or its many applications in the Industrial Arts.

I may, however, say briefly that the presentation of my Papers in the year 1888, giving an account of the Invention of Manganese Steel, took place in the Lecture Hall of the old building of the Institution of Civil Engineers. The first specimens of this Steel were produced on September 9th, 1882, and facsimile copies of my Experimental Records are shown in the Presidential Address I gave to the Faraday Society in 1914. It was without doubt largely due to the Papers then read and the assistance so ungrudgingly rendered to me by this great Institution, that the knowledge and uses of my material and its Scientific study spread so rapidly. Later on, Papers of similar nature were read by me before the Iron and Steel Institute in 1888, and the American Institute of Mining Engineers in 1893.

It was in America that Manganese Steel first received its encouragement on a large practical scale. Many helpers did yeoman work in grappling with the many difficulties which are inevitably met with in the manufacture and introduction of a new material. It may be interesting to add that at Highbridge, New Jersey, where the material was first made, there are the ruins of the old Forge which started work in 1742.

Although Manganese Steel was a troublesome material not only to understand and produce but to introduce, and owing to its peculiar hardness to deal with industrially, after the usual preliminary troubles experienced with most Inventions it rapidly rose to its present important position.

I am glad to say that my original Paper, read before the Institution of Civil Engineers in 1888, has stood the test of time, and if I was now asked to re-write it, I cannot find that it would be necessary to make any but trivial amendments, in fact as regards the accuracy of the data and facts there established, practically no changes.

It is a great satisfaction to me to know that the use of Manganese Steel in the War was found of such great advantage. As pointed out by Mr. George A. B. Dewar in his Book "The Great Munition Feat, 1914-18," tens of thousands of lives were saved and severe wounds avoided by the utilisation of this material for Helmets, and many lives would have been saved in 1914 and 1915 had these Helmets been then available. When making the Invention, although I could see from the many wonderful properties I found it to possess that the material had a great future, I never thought that seven to eight millions of human beings, British, Americans, and Belgians, would some day wear this steel upon their heads in the shape of "Tin Hats," as they were irreverently called. The superiority of Manganese Steel is well illustrated in Plate 19, in which is shown a comparison of its resistance with that of the material used by our French Allies and that used by the Germans.

The material was also used for Bodyguards and Leg protection. Owing to its great toughness and resistance to the impact of Shrapnel Bullets, Manganese Steel was found admirably to answer this purpose of defence.

Incidentally, as those versed in Metallurgical matters are aware, it is not an easy feat to reduce the hard material, Manganese Steel, from large-sized ingots to thin sheets only 20 B.W.G. (.036″) in thickness, such as is required for Helmets. It was not thought possible, and, in fact, if it had not been for the War pressure and the serious losses occurring through head wounds, it is doubtful whether this Steel would ever have forced its way to the front for this particular purpose.

Mr. J. Brodie, an Englishman, was probably the first to introduce Manganese Steel in the above connection. He did so in conjunction with Messrs. Thomas Firth and Sons, of Sheffield, and great credit is due for the part each of them played in the matter.

The great American Weekly *Life* on October 24th, 1918, in its Frontispiece gave an admirable picture—a remarkably clever presentment in colours of the Armies of the Allies—of which a reproduction is shown in Plate 20, of the ex-German Emperor offering up his sword to the Allies with the well-deserved footnote "Der Tag," the real day indeed! Every soldier is there depicted as wearing a British pattern of Helmet. Whilst not quite technically correct, it was so in the main, and this wonderful illustration will for many reasons ever be treasured by me, as it reminds me that over and over again wearers of the

PLATE 19.

The French Helmet.

Weight 23¼ ozs.

This Helmet is easily perforated by Shrapnel Bullets at as low a velocity as 350 feet per second.

The British Helmet. Manganese Steel.

Weight 25½ ozs.

This Helmet keeps out Shrapnel Bullets up to a velocity of about 750 to 900 f.s. (feet per second).

The German Helmet.

Weight 37 ozs.

This Helmet, although 12 ozs. heavier and 12 per cent. thicker than the Manganese Steel Helmet, is perforated at lower velocities. It also cracks badly under impact.

"Tin Hats" made of the material I invented have written or come to thank me for having saved their lives or avoided serious wounds. It is also a reminder of the splendid work carried out by this Paper during the War on behalf of the Great Cause. *Life* stimulated millions of Anglo-Saxons in both America and this country, and those who were responsible for its work and the control of its policy deserve the highest praise.

The first Steel Helmets were introduced by our French Allies, and were designed by General Adrien. Some two millions of them were manufactured and issued to the French Army. They were, however, only made of ordinary Mild Steel, the resistance of which was comparatively low, and they were anything but protective.

In a recent communication to the Academy of Science in Paris, Monsieur Charles Frémont, who has this year received the Bessemer Gold Medal from the British Iron and Steel Institute, gave some valuable comparisons of his method of testing thin plates by punching, including in these the resistance to punching of Manganese Steel Sheets such as used for Helmets. His facts are specially interesting and are given a little further on. During the early part of the War, and knowing the excellent results obtained by us here, I did my best to get the French Military Authorities to look into the subject and follow the example of the British Armies, but without avail.

Singular to say, the very week in which the Armistice was arranged the French Authorities sent over a special Commission —one of the members of which had worked with me on our Inventions Board in this Country—to see me in London with the object of discussing the immediate introduction of large quantities of Helmets made of Manganese Steel into the French Army. The British Minister of Munitions offered to send over 50,000 Helmets in a couple of days. The Committee returned to Paris and before a reply was possible the Armistice was signed. If the War had continued the French Army would therefore also have been equipped with Helmets made of Manganese Steel.

The tests by Monsieur Frémont to which I have referred showed that our Helmets possessed no less than 12 kgm. resistance as against only 7 kgm. for the French Steel Helmets. In one case Shrapnel Bullets fired at about 900 ft. seconds velocity perforated no less than three French Helmets placed in a row, whereas one of the same pattern of Helmet made of Manganese Steel attacked at the same velocity could not be perforated. No wonder we saved numerous lives and had fewer head wounds

as compared with the French who lost heavily for want of proper head protection.

In the same way, although not generally known, one important application of Manganese Steel was for certain kinds of Sprockets and Gears in connection with Tank construction, this being the only material which enables such parts of these War machines to stand the enormously severe wear and tear to which they are subjected.

Finally, towards the end of the War a curious application of the non-magnetic qualities of Manganese Steel was recorded, namely for the particularly dangerous and deadly Naval weapon known as the "Sea Mine." A considerable portion of this Mine was made of this non-magnetic material of high tenacity, the result being that the Enemy could not detect the presence of the Mines, as would have been the case had these been made of ordinary Iron or Steel, consequently many German Destroyers, Submarines, and other German craft met their fate from these Mines. Thus we have here an instance of the peculiar property of a Steel composed chiefly of the most magnetic metal known, that is Iron, being made use of for the purpose I have mentioned because of its non-magnetic qualities. Great credit is due to one of the Fellows of the Royal Society, Professor J. C. McLennan, who worked strenuously night and day upon this problem until the Mine was made successfully.

An amusing testimonial to the efficiency of Manganese Steel appeared recently in one of the American Technical Journals—it was an advertisement describing the qualities possessed by Manganese Steel, the following being the wording employed: "You can hammer it till the cows come home and it doesn't know you're knocking. That's why we put a Manganese insert in our Railway Frogs. Flange worn wheels don't make any more impression on it than a shipworm on an Armoured Cruiser." What a testimonial, but I am afraid somewhat exaggerated!

As I have said, it is quite impossible to give here a tithe of the applications of Manganese Steel. In the Trackwork of Railways and Tramways and for Crushing Machinery, its use has been invaluable, in fact, modern high speeds could not be attained and severe services met without it.

LOW HYSTERESIS STEEL

A Brief Reference to its Invention and Application.

On account of its importance and utility to the World a brief reference may be made to another of my Alloys, known as Low Hysteresis Steel, in respect of which I think we may without presumption claim that the World is again indebted to Sheffield for a further important product.

I described this Alloy of Iron and Silicon in my Paper entitled "Alloys of Iron and Silicon," read before the Iron and Steel Institute in 1889. This material, with the heat treatment I invented, has very remarkable qualities, of which the Electrical Engineer has been able to take advantage to the fullest degree. Under low magnetising forces this steel is, curious to say, even more magnetic than Iron itself, and largely reduces the waste of energy previously met with whether from hysteresis losses or eddy current losses. The Steel known as Low Hysteresis Steel is chiefly used in the construction of Transformers and other Electrical Apparatus.

I have worked out, from data kindly supplied to me by both British and American Electrical Experts, an approximate but conservative estimate of the annual saving to the World which has resulted from this particular invention of mine.

The total output of this steel has been about half a million tons, from which Transformers with a capacity of about 120 millions K.V.A. have been produced.

From the results of general practice and based upon working data, this total Transformer capacity is now effecting a saving of about 5 million tons of Coal each year. At the present price of Coal in this country, say 30*s*. per ton, this shows a present saving to the World of at least £7,000,000 in one year, that is in the economy of Coal consumption alone. This, too is quite apart from the considerably less weight of Copper required in the construction of the new type of Transformer, and the smaller space occupied, also a point of considerable advantage to the user.

Low Hysteresis Steel also possesses the valuable property of not ageing, in fact on the contrary, and singular to say, positively it improves with service. After being in use for a comparatively short time, the old Transformer material aged so

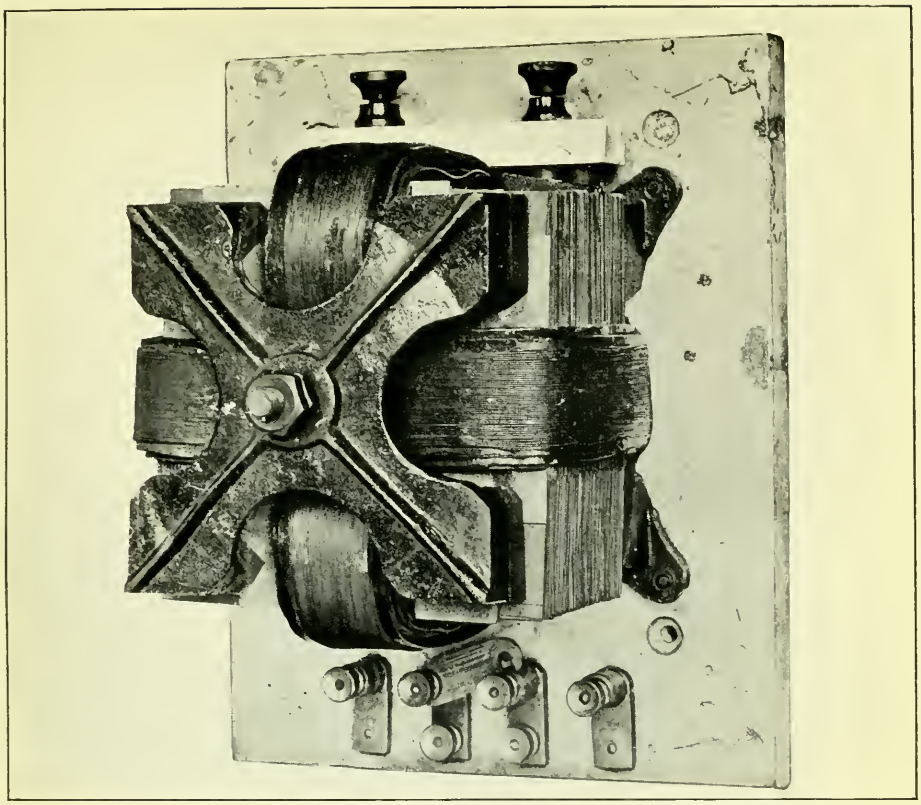
considerably that energy losses were appalling, sometimes becoming doubled and even quadrupled. In one case which came to my notice, a battery of Transformers made of the material used before my invention, showed at an early stage 5 per cent. to 7 per cent. of energy losses and in a year these had increased to no less than 20 per cent., that is, nearly one-fifth of the Coal employed to generate the energy was being wasted! No wonder that practically all Transformers and much other Electrical Apparatus are now made of the new material.

Probably since the introduction of the Low Hysteresis Steel, and making allowance for the much lower price of Coal at pre-War prices, the total saving to the World since its introduction has been greater than 27 million tons of Coal. Apart from the economy in Copper referred to and other benefits arising from the improved practice obtainable, this has meant a total definite and actual saving to the World during the time mentioned of at least about £13,000,000.

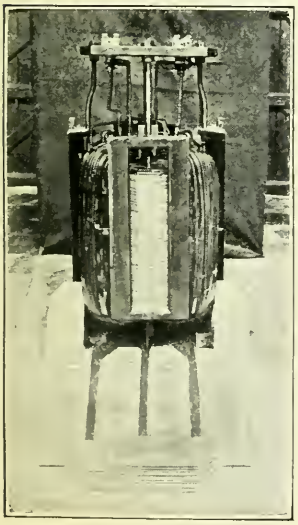
To show that my estimate of the large savings which have been effected by the use of Low Hysteresis material is a conservative one, I may add that a prominent American Scientist, Mr. T. D. Yensen, of the Research Laboratory of the Westinghouse Electric Company in America, recently contributed a valuable paper to the *Electric Journal* on the Development of Magnetic Materials.

In this article, based on special knowledge of the subject, he refers to my Low Hysteresis Steel and states that he estimates the total saving already effected to the World by this material in reducing energy losses, saving in Copper, better apparatus and other advantages, amounts to no less than 340 million dollars, or about *eighty million pounds sterling* at the present rate of exchange, and adds the words, "Nearly enough to build the Panama Canal."

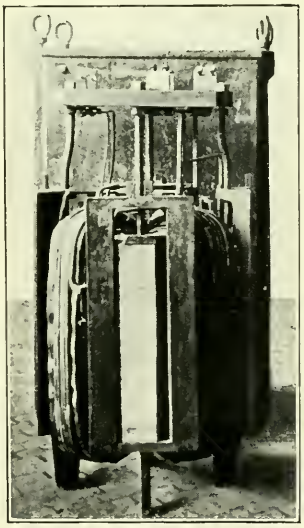
I have now in my possession the first experimental Transformer of this material. This Transformer weighs about 30 lbs. and was made and tested in the year 1903 by the Sheffield City Corporation Electrical Supply Department. In fact this same Transformer is being shown here to-night amongst the Exhibits, and a photograph is now thrown on the screen, Plate 21. The magnetising watts of this small Transformer were 15 watts as compared with 22½ watts for a similar Transformer constructed with "Lohys" Iron, the best material for the purpose then known (1903). This result was so satisfactory that the Manager of the Department, Mr. S. E. Fedden, M.Inst.C.E.,



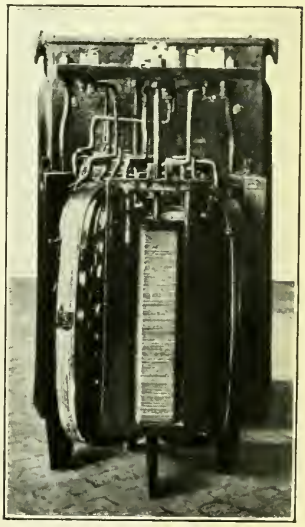
The Original Small Transformer, constructed in 1903, of Hadfield's Low Hysteresis Steel.



40 k.w. Transformer, constructed in 1905.



60 k.w. Transformer, constructed in 1906.



40 k.w. Transformer, of best Transformer Iron.

realising the important practical possibilities, at once agreed to the construction of two larger Transformers of 40 and 60 k.w. capacity. Full credit should be given to him for this wise decision.

The former, of 40 k.w. capacity (Plate 21), was put to work in June, 1905 on the Sheffield City Corporation Electrical Supply, and has since been continuously in use, that is, for a period of over 16 years.

In addition to a saving in weight of core material, the core weighing only 830 lbs. as against 1,120 lbs. for a similar Transformer using the best Transformer iron obtainable, the Magnetising Losses of this Transformer were only 176 watts as against 238 watts for best Transformer iron. While in use the Magnetising losses have steadily decreased, as shown by the following tests :—July 4th, 1905, 176 watts ; August 4th, 1905, 161 watts ; May 8th, 1906, 150 watts ; March 26th, 1912, 131 watts ; December 31st, 1915, 142 watts ; September 16th, 1919, 104 watts.

As regards the 60 k.w. Transformer (Plate 21), on account of advantage being taken of the special qualities of the Low Hysteresis Steel in reducing the size, this was small enough to go into a 40 k.w. tank.

The Magnetising Losses were originally 305 watts as compared with 330 watts for a Transformer of similar capacity using the best transformer iron.

This Transformer was put to work in July, 1906, on the Sheffield City Corporation Electrical Supply, and has been continually in use, that is for a period of over 15 years. While in use the Magnetising Losses have consistently decreased as shown by the following tests :—July 8th, 1906, 305 watts ; March 26th, 1912, 278 watts ; December 31st, 1915, 266 watts ; September 15th, 1919, 260 watts.

It will be seen that in both Transformers not only has there been no ageing, but there is actually a steady and continuous improvement in the core material.

The latest report with which Mr. Fedden has kindly furnished me is shown in Plate 22. Thus the material obtained its first Industrial application, and has now become the standard throughout the World. Unless there is some basic change in the construction of Electrical Appliances, it must necessarily continue to remain so.

Section XI

FEDERATION OF ENGINEERING INTERESTS

UNITED ENGINEERING COUNCIL

In view of the importance of federating the work of the British Engineer, I may add some comments on the work of the United Engineering Society, its Foundation, Council, and Great Building in New York.

The president of the United Engineering Society is Mr. Charles F. Rand, whose portrait was shown in the early part of this Address. The Society combines the four large American Engineering Societies as well as about twenty of the smaller Societies, and holds and administers the Engineering Societies' Building. Its work is somewhat similar in nature to that performed in this Country on a smaller scale by what is known as the Conjoint Board of Scientific and Technical Societies, which in its turn comprises some sixty British Scientific and Technical Societies. The United Engineering Society has three Departments, namely, the Engineering Societies' Library Board, the Engineering Foundation Board, and the Engineering Council.

The Engineering future of America is in the hands of the Engineering Foundation Board. This Foundation, which in its Charter is described as being "For the Furtherance of Research in Science and Engineering and for the Advancement in any other manner of the Profession of Engineering, and the good of mankind," was instituted on May 28th, 1914, by one of the recent visitors to London and one of America's leading Engineers, Mr. Ambrose Swasey of Cleveland, Ohio, to whom and to whose munificence as Founder of the Engineering Foundation I have already referred earlier in this Address. During his stay in this Country, Mr. Swasey deservedly became one of the most popular of men. His quiet charm of manner won all our hearts.

It may be of interest to refer here to the Federated American Engineering Societies, which resulted from the Conference organised in the United States and held in Washington on June 3rd and 4th, 1920. The first Meeting of the American Engineering Council took place on November 18th, 1920, at the New Willard Hotel, Washington, twenty-one Societies being represented, including all the large ones. There were also participating Organisations and Delegates representing ten other

Societies. It should be noted that the Societies included were those having their centre not only in New York, but in the various other cities throughout the vast area of the United States, and that this new movement represents a grand total of probably now over 200,000 Engineers.

To-day is the Era of the Technical Man, so the Building in which are centred his hopes, the records of his work, his Societies, is indeed an important one. The magnificent Engineering Societies' Building in New York, with all its wonderful conveniences, at the opening of which I was present on April 16th, 1907, was made possible in the first instance by the munificence of Mr. Andrew Carnegie, who gave towards its cost in all about one and a half million dollars. It is the one centre for Conferences and Meetings the reading of Papers, and other business for some sixty thousand Technical Men in the United States, including the four major Engineering Societies—Civil Engineers, Mining and Metallurgical Engineers, Mechanical Engineers, Electrical Engineers—and about twenty minor Societies—the Aeronautical Society of America, American Gas Institute, American Institute of Heating and Ventilating Engineers; Association of Edison Illuminating Companies, Empire State Gas and Electric Association, Illuminating Engineering Society, Municipal Engineers of the City of New York, National Association of Engine and Boat Manufacturers, National Americanisation Committee, National Electric Light Association, New York Electrical Society, Society for Electrical Development, Society of Automotive Engineers, Society of Naval Architects and Marine Engineers, United Engineering Society, Engineering Council, Engineering Foundation, John Fritz Medal Board of Award.

Another and important advantage that the Engineers of the United States possess is that they have one Library common to all the Societies, made available only for Scientific and Technical Literature, containing more than 150,000 different works. Owing to the addition of another floor, which was added during the War to house the American Society of Civil Engineers, the present height of the Building is nearly 300 feet, and alongside and directly connected with it is the Engineers' Club.

From this Building therefore spring many advantages, such as better co-ordination of work done, the avoidance of overlapping of Papers or Papers getting before the wrong Society, thus saving much valuable time and energy. Further, the

Secretaries can freely exchange views in a few minutes, and friction is avoided.

Someday, even if we do not have one Building for the British Technical Men throughout the Empire, at any rate we ought to have one Central Engineering Council, which would guard and foster Engineering interests of all kinds.

Of the four Founder Societies each pays about $12,000 per annum as its assessment for one floor's space in the Building, $4,000 per annum for the support of the Library, and $4,000 per annum for the support of the Engineering Council. Each of the Founder Societies gets a rebate on its $12,000 per annum, which is equivalent to 4 per cent. interest on $180,000, that is, $7,200 per annum. This is simply interest on money paid by the four Societies towards the cost of the land and building.

There are approximately twenty-six so-called participating Societies who occupy quarters in the Building, and they are assessed according to the space they occupy, that is on a smaller scale than the large Societies.

Whilst referring to Mr. Carnegie's great work, let us not forget his many other acts of munificence. The World owes him a deep and lasting debt of gratitude. He has gone from us, but his spirit of generosity will ever remain. It was not everyone who could sit down and in a brief letter give so much satisfaction to a very large number of his fellow-men as he did when he wrote the following words : " It affords me great pleasure to give, say $1,000,000, to erect a suitable Union Building for you all, as the same may be needed." This was followed by another gift of $500,000.

In this Country he gave handsome help to the Iron and Steel Institute, of which he was President immediately before my own Presidency of that Body, including the large sum of $100,000 to found the Carnegie Research Fund and Scholarships. Ever since 1901 this benefaction has done untold good in encouraging Metallurgical Research irrespective of Nationality or Sex. When the Scholarship Papers presented are considered of sufficient merit, the individual is awarded the Andrew Carnegie Gold Medal. As a Member of the Carnegie Scholarships Committee of the Iron and Steel Institute, I can bear testimony to the immense good resulting from this great man's munificent benefactions, not only to his own Country but to ours as well. Let us ever keep his name fresh in our memories.

When speaking of the Joint Engineering Societies' activities, I should like to refer specially to the work of two of their Secre-

taries with whom I have been in personal touch over a long term of years, and therefore take this opportunity of thanking them for their services and friendly aid on so many occasions. One is my friend, Mr. Calvin W. Rice, the Secretary of the American Society of Mechanical Engineers, who along with Professor Charles Scott of Yale University received from the late Mr. Andrew Carnegie his great gift of the Engineering Societies' Building and the Building of the Engineers' Club in New York. The other is Professor Bradley Stoughton, past Secretary of the American Institute of Mining and Metallurgical Engineers. He has been an indefatigable worker on behalf of the Science of Metallurgy.

FEDERATION OF ENGINEERING INSTITUTIONS

During the recent visit of the Deputation of American Engineers to London, the opportunity was taken to exchange ideas with British Engineers regarding organisation on subjects of international importance including Research and other matters. Out of this friendly Conference I believe will spring most important results. The Institution of Mechanical Engineers in this Country has already appointed a Special Committee known as the Committee of the Federation of Engineering Institutions, to study closely the question of uniting the interests of British Engineers, and to profit by the example and great work already accomplished by the Engineering Society in America with its Foundation, Council, and great Building. Another aim of the Special Committee here, along with the American Committee, will be to try eventually to bring together and unify the interests of the English-speaking Engineers throughout the World.

The members of the Committee are Mr. W. H. Patchell (Chairman), Captain H. Riall Sankey (the present President), Sir John Dewrance, Professor W. E. Dalby, Mr. L. A. Legros, Mr. D. B. Morison, Mr. L. Pendred, Mr. W. Reavell, and myself.

I am particularly pleased to find that several of the suggestions made in my Address of Thanks to the Deputation from the Engineering Societies of the United States are being taken up very cordially in America. One of them was that there should be a Federation represented by a Council of Engineers, for all

Anglo-Saxon-speaking people. In my humble opinion such an organisation would speak with greater force than that of the Politician in either Country. The Engineering Council of New York, representing some quarter of a million Engineers of different classes, has ordered 500 copies of my Address for distribution on the other side, with a view to fully disseminating this suggestion.

THE ENGINEERS' CLUBS IN LONDON AND NEW YORK

It may be of interest to show upon the screen the great Engineering Building in New York, towering as it does to a height of nearly three hundred feet, and in which the activities of the different classes of Engineers are all centred. Close alongside this Building is the Engineers' Club. Plate 23 shows this Building in New York, and Plate 24 the Engineers' Club in Coventry Street, London, which has recently been successfully formed.

The total Membership of the latter has now reached 3,500, made up of 1,800 Town, 1,250 Country and 450 Foreign and Overseas Members. This seems to show the need that exists for a home for Engineers in London. It is hoped that this Club will specially meet the wants of British Engineers visiting the Mother Country.

The Club premises in Coventry Street, W.1, comprise many fine public rooms. There are three Dining Rooms, each capable of comfortably seating 85 at small tables or 125 at set banquets. Lunch can be served to 250 persons simultaneously. To one of these rooms, and to that room only, ladies, accompanied by a member, are admitted from 6.0 p.m. to 10.30 p.m., and a feature will be made of a special theatre dinner. The Billiard Room is stated to be one of the finest in London, with five tables by Burroughs and Watts, and a fine Lounge where 70 or 80 can sit in comfort without in the least interfering with the players at the tables. There are three rooms for cards, chess, etc., a smoking lounge, and a very good reading room and library. The smoke room on the ground floor is one of the features of the Club. The larger rooms have been named after famous men of past days in the professions represented by the Club Membership. These are: "The Trevithick," "The Kelvin," "The Watt," "The

PLATE 23.

The Engineering Building and Club, New York.

PLATE 24.

The Engineers' Club, Coventry Street, London, W.

Stephenson," "The Faraday," "The Telford," "The Wren," "The Joule," and "The Dalton" rooms.

As Mr. Edmund L. Hill, of the Federation of British Industries, who has done so much in establishing the Engineers' Club, rightly says: "May it not be hoped that the time will come before long when those sections of Science represented by Engineering, Metallurgy, Chemistry, Architecture and other branches will build themselves a home worthy of their calling and of the Empire."

I have suggested to the Committee of this new Engineers' Club that they should try to bring about an arrangement by which British Engineers should be granted the courtesies of the American Engineers' Club in New York, and American Engineers visiting this Country should have similar courtesies extended by the new Club here.

Section XII

ELECTRICAL POWER

In view of the importance of cheap power to the Metallurgist who would like to use entirely the clean, controllable, and easily varied temperature of the Electric Furnace, whether as regards Melting or Heating, it occurred to me that the following statements with regard to the resources of natural power might be of interest. Who knows that the future source of smelting Iron may not be alongside some of the many great water sources of energy, possibly from the tides themselves ?

The source of everything is energy, the greatest centre being that gigantic entity we call the Sun, so no wonder there are Sun Worshippers. Nevertheless, the Sun itself falls into insignificance, we are told, alongside some of the still larger members of the Universe.

The amount of energy given off by the Sun, and upon which we depend for our very existence, is, I suppose, almost impossible for the human mind to conceive or express.

Although only a very small portion is incident on the Earth, no doubt we shall some day find ways of tapping this gigantic power, given off as it is during every instant of what we term " Time."

The cost at which energy can be obtained is most important, and a cheap source is of vital necessity to us as an Industrial Nation. As an instance I may mention that the Power House of the Sheffield Corporation, with its able Manager, Mr. S. E. Fedden at the head, rendered splendid service in the War.

My Firm melted during that period of stress some one hundred thousand tons of steel, which otherwise would have been wasted or of very little use even as Scrap. I refer specially to the utilisation of turnings, which are not easy to handle.

This further leads to the question as to whether what is now termed " white " coal, that is energy obtained from water power, will be able to compete with " black " coal. Our sources of water power are none too numerous, so it may be interesting to see what is being and what may be done abroad ; I want to speak briefly this evening about some of those sources. There are, for example, Niagara, both American and Canadian, and many other centres in Canada ; Norway and Sweden, and finally one great source which has not yet been tapped, the Victoria

Falls in Africa, with which I shall specially deal. In this connection I have been able to obtain certain pictures which I believe have not before been shown in this country.

NIAGARA FALLS

Like many others, I have in former days stood before Niagara Falls, and as a utilitarian bemoaned the enormous amount of energy being wasted there. I remember that at my first visit the whole of that energy was running to waste, and at my second only a small amount was being utilised.

Early Niagara Estimates

I was led to investigate this subject by a recent reading of the remarks of the late Sir William Siemens, who, in his Presidential Address to the Iron and Steel Institute in 1877, spoke of Niagara Falls, that is the principal Fall alone, and estimated that the energy running to waste there was no less than 17,000,000 of horse power per hour. Taking the consumption of coal at 4 lbs. per horse power per hour, this would have corresponded to 266,000,000 tons of coal per annum. His estimate for the two Falls together would have been several millions of horse power more, or a total probably over 20,000,000 of horse power.

It can be understood that anybody seeing the Falls in those days would rather have been inclined to make such an estimate "billions" of horse power instead of "millions." The human mind shows a curious tendency to exaggerate the unknown, and this is evidently one of the cases.

At that time there had been but comparatively little utilisation of water power energy, and Sir William Siemens cannot be blamed for his estimate, though it was far too high. Nevertheless, as events have shown, Sir William was quite correct with regard to his prediction as to the future importance of electrical energy developed from water power.

Francis Lynde Stetson, writing in 1895, stated that the ordinary flow over Niagara had been found to be about 275,000 cubic feet per second, and the daily energy developed was equal to the latent power of all the coal mined in the world each day—something more than 200,000 tons daily. At the time Professor Unwin computed that the falls represented theoretically seven

million horse power, and for practical use, without appreciable diminution of the natural beauty, several hundreds of thousands of horse power.

In 1885 about 10,000 horse power was developed by water wheels for various mills. The energy now utilised is about 750,000 horse power.

At the present time Auto-wheel Alternators of 32,500 K.V.A. power are being put to work at Niagara.

Actual Figures

In view of the considerable later development of these wonderful Falls, it occurred to me that it would be interesting to know about how much energy could be obtained from them. I am indebted to my American friends, Mr. W. S. Murray, Chairman of the Engineering Staff of the Super-Power Survey of the United States Geological Survey, Department of the Interior, and Mr. L. E. Imlay, who is on the Staff of the Engineering Survey in question, for the following important data :

It appears that the present American developments aggregate about 300,000 horse power, and the Canadian 385,000 horse power. In the Chippewa development on the Canadian side, now being constructed, there will be a considerable increase. In making up the estimate, it may be stated that the Niagara Falls at times flows at a rate of 300 foot seconds, and goes down to as low as 175 foot seconds. The hydraulic head of the Upper Falls is 220 feet and the total average fall between Lake Erie and Lake Ontario is 310 feet. The Canadian development at Chippewa embraces the full 310 feet.

The following table gives the horse power using an average and minimum flow and shows what will be the total horse power when utilising 60 per cent. of the average flow, the remaining 40 per cent. being required for scenic effect at the Falls. This latter percentage is the estimate made by Mr. W. S. Murray. If the utilitarian question is considered, there is no reason why a larger proportion should not be devoted to manufacturing purposes.

	Horse power at 60% average water to be utilised for industry.	Nearly 40% required for scenic effect.	Total horse power, using al the water at Niagara.	
			Average flow.	Minimum flow.
Upper Falls .. (220 Head)	2,700,000	1,800,000	4,500,000	3,600,000
Total Falls .. (210 Head)	3,720,000	2,480,000	6,200,000	4,960,000

Scottish Water Power Schemes

An account of the interesting Scottish water power schemes has been described recently in *Engineering*. One known as the Lochaber scheme is estimated to cost nearly £3,000,000, the engineers being Messrs. S. S. Meek & Buchanan and Sir Alexander Binnie, Son & Dean. The British Aluminium Company will largely utilise this power at Fort William. For the Grampian scheme the engineers are Messrs. Mott, May and Anderson, in conjunction with Signor Angelo Omodeo.

These are all outcomes of the schemes recommended by the Water Power Research Committee appointed by the British Board of Trade in 1918, with Sir John Snell as Chairman.

As I understand, the Lochaber scheme, whilst at present contemplating 72,000 electric horse power, will have in view further development increasing this to 100,000 electric horse power. The Grampian scheme will also be on a comparatively large scale.

I refer to these schemes because they show that attention is being paid in Great Britain to the development of the utilisation of "white" coal, but it will be seen how comparatively puny these are alongside the power of mighty Niagara.

London Comparison

As a comparison it may be interesting to state that the total horse power developed in the great city of London (Metropolitan area), from definite data for which I am indebted to Mr. G. W. Partridge, M.I.C.E., of the London Electric Supply Corporation, amounts to 2,055,000 horse power, of which 1,400,000 horse power is used to develop electrical energy for lighting and industrial purposes, 190,000 horse power for working tramways and railways, and the balance of 465,000 horse power is produced by steam, gas, etc.

It must be borne in mind that these figures represent horse power expressed in terms of steam or mechanical horse power, *i.e.*, one horse power equals .746 of an electrical unit, or one k.w.

From the above it will be seen that the energy already being utilised from the Niagara Falls is sufficient to furnish about half of all the horse power used in this great Metropolitan city with its 8,000,000 inhabitants. On the other hand, if Niagara were fully developed on the lines indicated in my remarks, there would be enough energy developed to supply a city of double or two and a half times the size of London.

I now throw on the screen Plate 25, showing a map of Central Africa, illustrating the scheme devised for supplying Electrical Power from the Victoria Falls, and distributing this over a considerable area. The idea of trying to harness the Victoria Falls originated in the following way, though singular to say nothing has yet been done. Some time during 1895 Mr. Alfred H. Haggard, a brother of the famous novelist, Sir Rider Haggard, and Professor George Forbes (who was one of the Engineers responsible for a portion of the Power Installation at the Niagara Falls), suggested to Mr. W. A. Wills, Chairman of the African Concessions Syndicate, Ltd., that he should apply to Mr. Rhodes, then Managing Director of the Chartered Company, for a concession to develop electric power from the Victoria Falls.

On arriving at Cape Town, however, Mr. Rhodes said he had received a similar proposal from Mr. H. B. Marshall, the well-known Johannesburg Financier, who suggested there should be a combination of forces. This plan was adopted, resulting in the formation of the African Concessions Syndicate Limited, who own the rights for 75 years for developing electrical power at the Falls.

The Chartered Company in the concession have stipulated that any installation shall not interfere with the supreme beauty of these stupendous Falls, a point with which I am sure you will agree after seeing the Cinema Pictures I now present.

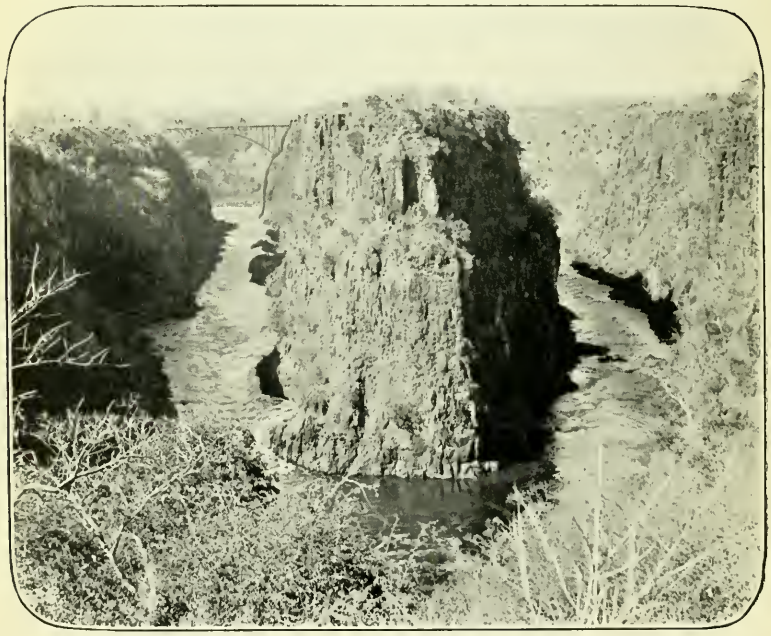
In 1855 that great British explorer, Dr. Livingstone, during his Missionary travels and Research in South Africa, described the Falls, in fact he discovered them, being the first White man to see them. He mentioned that five or six miles away five separate columns of vapour, almost lighter than smoke, were discernible. When the river is in flood or full, the columns, it is said, can be seen ten miles away, and the roar of the falling water is also heard at that distance. One of the natives who accompanied Livingstone asked him, "Have you smoke that sounds in your country ?"

Livingstone said of his visit to the Falls that they had never before been seen by European eyes, adding "but scenes so lovely must have been gazed upon by the angels in their flight." One can understand this poetical conception from the beautiful view shown in Plate 26. He added that "when about half a mile from the Falls, I left the canoe by which we had come

PLATE 26.

The Victoria Falls from the Eastern Extremity.

PLATE 28.



The Victoria Falls, Profile Point.

AEROPLANE VIEW OF THE VICTORIA FALLS.

Taken by Sir Pierre van Ryneveld at an altitude of 3,000 feet, from the "Silver Queen," on his Cairo to Capetown flight.

The Falls are approximately one mile in width, the view showing nearly the whole of this.

down thus far, and embarked in a lighter one, with men well acquainted with the rapids, who, by passing down the centre of the stream in the eddies and still places caused by many jutting rocks, brought me to an island situated in the middle of the river, and on the edge of the lip, over which the water rolls. In coming thither there was danger of being swept down by the streams which rushed along on each side of the island; but the river was now low, and we sailed where it is totally impossible to go when the water is high. But though we had reached the island and were within a few yards of the spot, a view from which would solve the whole problem, I believe that no one could perceive where the vast body of water went; it seemed to lose itself in the earth, the opposite lip of the fissure into which it disappeared being only 80 feet distant. At least I did not comprehend it until, creeping with awe to the verge, I peered down into a large rent which had been made from bank to bank of the broad Zambesi, and saw that a stream of a thousand yards broad, leaped down a hundred feet, and then became suddenly compressed into a space of fifteen or twenty yards. The entire Falls are simply a crack made in a hard basaltic rock from the right to the left bank of the Zambesi, and then prolonged from the left bank away through thirty or forty miles of hills."

It is interesting to note that later on the Victoria Falls were visited by Sir Richard Glyn and his brother when on a hunting excursion in 1863. They visited Garden Island and found the tree on which David Livingstone had engraved his initials, "D. L.," in 1855 when the discovery of the Victoria Falls by that wonderful explorer took place.

I have much pleasure in showing this evening the photograph (Plate 27) of the Victoria Falls of the Zambesi, taken last year from an aeroplane, the *Silver Queen*, at an altitude of 3,000 feet, by Sir Pierre van Ryneveld, on his Cairo to Cape Town flight. This view shows nearly the whole edge of the falls, which are approximately one mile in width. The height from the lip to the bottom is 420 feet, or two and a half times the height of Niagara. The Island on the extreme left of the lip is "Cataract Island." The next one is Livingstone Island, from which Dr. Livingstone first saw the Falls in 1855. The Victoria Falls railway bridge is stated to be one of the highest in the World, and may be seen in the bottom left hand corner.

From figures supplied by the Surveyor General of Northern Rhodesia, we are able to get an exact comparison between the width and fall of the two great Waterfalls, Victoria and Niagara.

At the point where the river dashes over the precipice the Zambesi is 3,000 yards wide, while Niagara is less than 1,000 yards at the famous Falls. The average drop of the Victoria Falls is 420 feet as against Niagara's 162. The discharge of the Zambesi is from 60 to 100 million gallons per minute, against 222,000 (mean) or 176,000 (low-water) cubic feet per second of the Niagara. If we reduce these to a common denominator we have the following interesting comparisons in volume. At high water the Zambesi discharges 100,000,000 gallons per minute against Niagara's 83,000,000 gallons, mean. At low water the volume of the water passing over Victoria Falls is 60,000,000 gallons, while at Niagara 66,100,000 gallons in the same interval.

If we express this in tons of 2,000 pounds we find that the Zambesi, at high water, discharges 30,000,000 tons per hour against Niagara's 24,975,000. At low water the figures are Niagara 19,830,000 and the Zambesi 18,000,000 tons. If we accept as mean at Victoria Falls low water plus one half of the difference between the extremes it appears that the discharge of Niagara is slightly in excess of that of the Zambesi at the Falls, the mean figure being Victoria Falls 24,000,000 tons per hour and Niagara 24,975,000.

It is interesting to bear in mind that while the Zambesi tosses headlong over a level sheet of basaltic rock, after flowing rather placidly along from its source near the West Coast of Africa for 1,000 miles, the Niagara rushes over limestone cliffs. The result is, while the Victoria Falls remain but slightly changed through the ages, the limestone cliffs of Niagara are being gradually washed away. It is estimated that every year the river takes away 5 feet of the promontory, and it is said the Horseshoe Fall has worn back the cliff 335 feet in 63 years.

On the other hand, the two miles outline of Victoria Falls has undergone no appreciable change during the time it has been under observation, owing, of course, to the adamantine nature of the precipice. Plate 28, which is a photograph of Profile Point, shows the nature of the rock in the narrow channel below the Falls.

Singular to say, at the present time there is no utilisation of this enormous energy, as it was found that ordinary power stations run by coal near at hand would prove more economical whether as regards Capital required or subsequent working charges.

Whilst I do not wish to preach a homily, nor to appear unduly optimistic, I cannot help thinking that the illustrations

I have shown you of the Victoria Falls, representing as they do a little corner of one of the Empire's outlying districts, help to show some of the enormous resources possessed by our Empire which will some day be utilised.

I think we are sometimes apt to forget that although the War has been a great strain upon us, nevertheless the outcome is that we are more powerful, stronger, and possess still greater resources than ever. The additions to the Territories coming under the control of our Empire since November, 1918, have been enormous. As soon as we can shake off the present mental and physical apathy and come up to the realities of the situation and get to work, I think we shall find that developments of all kinds will result in increased prosperity and greater comfort to all concerned. It is a pity certain sections amongst us do not see this. Let us take a lesson from the busy Bee.

I am indebted to Mr. Leo Weinthal, O.B.E., of the African Publications, Ltd., for being so kind as to furnish me with some of the foregoing information regarding the Victoria Falls, and the beautiful cinema pictures which I hope will please you.

Whilst speaking of power production, it would perhaps be interesting to compare costs from (*a*) water power, (*b*) steam power. In a comparatively recent statement by the American Boiler Manufacturers' Association, reference is made to the combination of high ratings and high efficiency now obtained in certain well ordered plants. It is stated that in the Buffalo General Electric Plant 400 per cent. of the nominal rating is obtained at a high combined efficiency of boiler and furnace.

Professor Bone in his "Bonecourt" boiler, which it is hoped by further improvements to work up to final success, has succeeded in producing efficiencies of about 84 per cent., together with a boiler rating of one boiler horse power per square foot of heating surface, which corresponds to no less than 1,000 per cent. capacity. This refers to the nominal rating of 10 square feet per boiler horse power.

In the American Report above mentioned, it is pointed out how great is the importance of utilising energy in every possible way. Therefore, whilst water power development may not in every case be financially attractive, yet every kilowatt hour developed by water power means a direct saving in fuel consumption.

RAPID CINEMATOGRAPHY

It may be interesting to those attending this Lecture to know that, in reference to the development and increasing importance of Cinematography, Mr. Walter Heape, F.R.S., has been experimenting with a new photographic machine—the Heape & Grylls rapid cinema—which takes film photographs at the rate of from 500 to 5,000 *per second.* At the latter speed the film is driven at the rate of just over four miles per minute; this means driving a drum 6 ft. diameter, 1,000 r.p.m. and two 10 in. diameter lens wheels, with 40 lenses in each wheel, 7,200 r.p.m. This naturally involves a heavy machine, weighing over three tons, and requires for its housing a structure about 12 ft. by 6 ft. by 10 ft.

Mr. Heape says it would be quite possible to construct a machine which would take photographs with F_4 lenses at the rate of 10,000 per second, while if F_2 lenses were used the rate would be increased to say 30,000 per second.

Important research work is going to be undertaken with this apparatus, by means of which no doubt many new facts will be obtained.

AMERICAN RAILROADS AND THEIR LONG TRAINS

RAILROAD practice and advance are mainly concerned with the progress of metallurgy ; for example, Bessemer's method of steel making was undoubtedly one of the chief factors in the rapid extension of the Railway Systems of the World.

As showing the mammoth proportions at which Americans are now aiming on their Railroad System, the following information may be of general interest, and it almost takes one's breath away. If American trains keep growing at this rate, then even the American Continent will some day not be big enough for them !

On the Virginian Railroad a trial trip was recently made of probably the longest train which has ever run on rails. On May 27th, 1921, a test train was made up of 100 loaded 120 ton cars, and an observation car. Five locomotives were required to start this train out of the yard at Princetown, but afterwards three were detached at the yard limit, leaving a Mallet pusher locomotive at the rear, and at the head of the train one of the new A.E. type engines, the heaviest and most powerful locomotives in the world, having a total weight, including tender, of 401 tons. The pusher was detached at Merrimac, and after the heavy engine had worked the train down the subsequent steep grade, the load was further increased by ten more loaded 120 ton cars, of which 111 in all were now being hauled. The length of the complete train was approximately 6,100 feet (1.155 or about $1\frac{1}{6}$ miles). This total load of 15,400 gross tons constituted a World's record, and was hauled over 250 comparatively level miles between Roanoke and Sewall's Point without assistance.

In comparison it may be mentioned that the heaviest English locomotive weighs, in working order, 140 tons. The maximum tractive capacity on a level track of the latest Great Western Railway, Great Central Railway, and Great Northern Railway 2.8.0. mineral engines, in this country, may be taken at from 2,000 to 2,500 tons behind the tender. It is difficult, however, to give an exact figure in view of the absence of published test results as to maximum loading.

I am indebted for data regarding the British practice to my friend Sir Henry Thornton, K.B.E., General Manager of the Great Eastern Railway.

As Sir Henry points out, the type of locomotive train and car which are satisfactory for America are not wholly suitable or necessary here. He does think, however, that we could advantageously build and use cars in this country up to 30 tons, and possibly 40 tons, capacity.

AN APPRECIATION OF ANCIENT RESEARCH WORKERS

A REMARKABLE volume has recently appeared entitled "A New System of Scientific Procedure," by Mr. C. Spiller, Author of "The Mind of Man," and other books, who is now a Member of the Intelligence Service of the Scientific Division of the International Labour Office, Geneva.

In one of the chapters, Mr. Spiller (whose book is "Dedicated to the imperishable memory of Francis Bacon, the founder of Scientific Methodology") discusses the work of the great precursor of modern Science, Francis Bacon, to whom I refer so fully later on in this Address.

Mr. Spiller points out that Bacon characterised the Scientific thinker by attributing to him largeness of capacity, faithfulness of memory, swiftness of apprehension, and penetration of judgment. This he set forth about 1620 in the Dedication to the "Advancement of Learning." Bacon's words are as follows: "For myself I found that I was fitted for nothing so "well as for the study of Truth; as having a mind nimble and "versatile enough to catch the resemblance of things (which is "the chief point), and at the same time steady enough to fix "and distinguish their subtler differences; as being gifted by "nature with desire to seek, patience to doubt, fondness to "meditate, slowness to assert, readiness to reconsider, careful-"ness to dispose and set in order; and as being a man that "neither affects what is new nor admires what is old, and that "hates every kind of imposture" (De interpretationes Naturæ Procœmium—Spedding's translation).

Mr. Spiller also mentions several points which are often apt to be overlooked. One of them I have emphasised in several of my Addresses and Papers, that is, I have always tried to do full justice to the Workers of the past, for it is largely from their wise prevision that we are to-day benefiting so largely. As Mr. Spiller rightly states, it would be a grave and unpardonable error to suppose that every Invention and Discovery of note dates from the rise or Era of Modern Science. Long before that Era man had invented language, alphabets, the arithmetical notation now in use, also customs, manners, morals, religions, and laws; domesticated diverse animals; developed the cereals,

vegetables, and fruits, and discovered the use and safe production of fire; extracted, utilised, and mixed various metals; introduced the axe, the knife, the saw, the plough, the wheel, glass, mirror, sails, bricks, windmill and watermill, the calendar, the compass, spectacles, clocks, and scores of other Inventions and Discoveries of far-reaching significance; built magnificent roads, waterways, carriages, ships, and temples; produced unsurpassed works of art, and developed man's sense of the beautiful; and laid the foundations of mathematics, astronomy, logic, and medicine, besides those of poetry, the drama, and literature generally. In these circumstances, whilst meting out ample justice to Modern Science, it behoves us to speak with profound appreciation of what men accomplished in the remote past.

Spiller points out that Alfred Russell Wallace has stated that on the other hand the nineteenth century is responsible for the subjoined first-class inventions—railways, steam navigation, electric telegraphs, the telephone, friction matches, gas lighting, photography, the phonograph, Rontgen rays, spectrum analysis, the use of anæsthetics, and the employment of antiseptics—a truly wonderful output for *one* century. There are also many other important advances in the Science of Engineering and Metallurgy which might be added.

The Bust in the centre of the Engraving represents King Charles II, the figure on the right Francis Bacon, and that on the left Lord Brouncker, the First President of the Royal Society.

From an Engraving by W. Holler in the Book by Thomas Sprat, D.D., F.R.S., Lord Bishop of Rochester, entitled "The History of the Royal Society of London for the Improving of Natural Knowledge," published in 1667.

THE GROWTH OF SCIENCE, INCLUDING A BRIEF GLANCE AT THE HISTORY AND WORK OF THE ROYAL SOCIETY FROM ITS INCORPORATION IN 1662

EARLY HISTORY OF THE ROYAL SOCIETY

The Charter of Incorporation of the Royal Society, marking the date of the commencement of the great work, passed the Great Seal on the 15th July, 1662. It was read before the Society on the 13th August of the same year, and on the 29th, the President, Council and Fellows went to Whitehall in order to return their thanks to His Majesty King Charles II.

Previous to the Charter being granted, a Meeting had been held on the 5th December, 1660, and the Signatures are extant of the forty-one persons who on that date resolved to form the Society for promoting Experimental Philosophy.

At every meeting of the Council and of the Society since its foundation, the Mace, " of the same fashion and bigness as those carried before His Majesty," presented to the Society by Charles II in May, 1663, as a mark of the Royal Favour, is laid on the table in front of the President before the business of the day is begun. This Mace weighs one hundred and fifty ozs. (Troy weight). It is of silver, richly gilt, and consists of a stem handsomely chased with a running pattern of roses and thistles, terminated at the upper end by an urn-shaped head, surmounted by a crown, ball and cross. On the head are embossed figures of a rose, harp, thistle and fleur-de-lys, emblematic of England, Ireland, Scotland and France, on each side of which are the letters C.R. Under the crown, and at the top of the head, the Royal Arms appear very richly chased; and at the other extremity of the stem are two shields, the one bearing the Arms of the Society and the other an inscription.

I have been a Fellow since 1909 of this ancient and renowned Body, to which the World generally owes a debt of gratitude for its ever fostering care of Science and Scientific development. My connection with the Society during the last and this year as a member of Council, has necessarily given me the opportunity of seeing and knowing its inner working, its aims and objects. These would satisfy even Bacon himself, who was so largely

responsible for the origination of the Royal Society. Without doubt its foundation was one of the earliest fruits of his philosophical labours and his great aim was to enforce patient investigation of Nature by observation and experiment, as compared with the deductive method which till then had been in vogue.

Singular to say, Bacon seems to have been unable himself to admit that the Inventions and Investigations made before his time were due to Science, but regarded them as happy accidents of chance. In this respect he was, for example, wrong to ignore Gilbert's great Scientific work on Magnetism, which was published in 1600 before the earliest of Bacon's Philosophical Treatises.

FRANCIS BACON

Dr. Gough in the excellent preface to his edition (1915) of *The New Atlantis* of the great Francis Bacon, Lord Verulam, Viscount St. Alban (Plate 29), first published in 1627, that is the year after his death, points out the great services to the cause of Science rendered by Bacon. His life work was to advocate Philosophical and Scientific reform. He claimed "that the sovereignty of man lieth hid in knowledge; wherein many things are reserved which Kings with their treasures cannot buy nor with their force command."

In one of Bacon's contributions he stated that he had looked round to find in what way he could best serve mankind and that he found "There was none so great as the Discovery of new Arts, Endowments and Commodities for the bettering of man's life." Also, "But if a man should succeed, not by striking out some particular Invention, however useful, but in kindling a light in Nature, a light that should in its very rising touch and illuminate all the border regions that confine upon the circle of our present knowledge; and so spreading further and further should presently disclose and bring into sight all that is most hidden and secret in the world—I thought that man would be the benefactor indeed of the human race—the propagator of man's empire over the universe, the champion of liberty, the conqueror and subduer of necessities."

As Dr. Gough points out, Bacon was not content with explaining to the learned world the method which he believed would revolutionise Science; he was eager to "set the machine on work." In some secret memoranda, the *Commentarius solutus*, which he

Portrait of FRANCIS BACON, Baron of Verulam, Viscount St. Alban (1561-1626), Lord Chancellor of England, who inspired the Royal Society.

Fr. Verulam Cancr

From the Picture in the possession of the Royal Society

jotted down in the summer of 1608, he stated that he proposed to superintend the compilation of a History of Marvels, *i.e.*, of apparently abnormal phenomena, and a History of Mechanical Inventions. He included the foundation of a College for Inventors; two Galleries with Statues for Inventors past, and spaces or bases for Inventors to come; and a Library and an Enginary. The *Novum Organum*, that is "The New Instrument" (published in 1620) represented the mature presentation of his system. This "New Instrument" is contrasted with the old instrument for the attainment of knowledge, the syllogistic logic of Aristotle and his mediæval disciples.

Bacon showed "that we can only gain power over Nature and make her serve our purposes by discovering and imitating her modes of action." "Parendo vincitur." He showed that it was not enough to proceed by the blind and stumbling empirical methods hitherto in vogue, but that we must examine the instances we have collected to find the formal cause of that nature, or in Bacon's technical language, its "form." These "forms" are, as Bacon observes, the laws which govern and constitute simple natures.

It was in *The New Atlantis* of Bacon, left when he died in 1626, and which should be read by all, that he foreshadowed the future, the main feature of this being Solomon's House, "a Philosophical College," which was the embodiment of his life-long dream, and really the forerunner and a prophetic scheme of the foundation and work of the Royal Society that was to be. His projected College was to consist of a Company of thirty-six "Fellows," this being the word chosen and used by Bacon, and this appellation has continued ever since. As Dr. Gough says, a convenient setting for his tale was suggested by Plato's myth of Atlantis, contained in the *Timæus* and the *Critias*, and Plato's conception of periodic catastrophies and vanished civilisations swayed Bacon's imagination, hence *The New Atlantis*. To the modern reader it may seem a bold and indeed absurd flight of the fancy regarding the origin of America and its native population, but to Bacon it was a perfectly serious theory. The discovery of America about that time, and the strange isolated civilisations of Mexico and Peru, had naturally aroused much speculation, and Bacon's belief that America was the wreck of the submerged Atlantis was shared by many in his age.

Dr. Gough further points out that it would be false to deny such a great man as Bacon the supreme honours of a pioneer. Though others of his time had a greater gift for Scientific

Research, none was able to make so comprehensive a survey of the Sciences as he, or to recognise like him the unity of the realm of Nature. None was so equally conscious of the issues at stake, or had so clear a vision of the conquests that the new spirit was to make. None urged so convincingly the dignity and the practical value to mankind of organised Scientific effort. By proclaiming that mere tradition must be abandoned, that progress depends upon observation and experiment, that induction must proceed by selection and elimination and end with deduction, that true knowledge is the knowledge of causes, and that such knowledge is power, he gave eloquent expression to the scattered and unformulated thoughts of many minds. His importance lay, not in drawing up a code of rules of procedure but in stimulating thought. In his own words, he was the bell that called the other wits together. In the lofty imagery of Cowley's *Ode to the Royal Society*, Bacon was the Moses who led the chosen hosts to the borders of the Promised Land, which he viewed from the top of Pisgah, though he might not enter it.

Bacon's ability was of the highest order and he had a happy manner of dealing with those with whom he came in contact. There is, for example, his finely expressed letter to George Villiers, afterwards Duke of Buckingham, who subsequently became Prime Minister. In this letter he said : " You are as a new rising star and the eyes of all men are upon you ; let not your own negligence make you fall like a meteor. . . . Thus may you live long, a happy instrument for your King and Country ; you shall not be a meteor or a blazing star, but ' stella fixa,' happy here and hereafter. *Deus manu sua te ducat*, which is the hearty prayer of your most obliged and devoted servant, Francis Bacon."

Some further interesting words regarding Bacon seem worthy of being quoted. They are by the Rev. William Rawley, Doctor in Divinity, his Lordship's First and Last Chaplain, and are given in a book of several hundred pages called *The Resuscitatio, or bringing into Publick Light several pieces of the Works, Civil, Historical, Philosophical, and Theological, hitherto sleeping of the Right Honourable Francis Bacon.* Rawley states that Bacon " was no dashing man, as some men are, but ever a countenancer and fosterer of another man's parts. Neither was he one who would appropriate the speech wholly to himself, or delight to outvie others, but leave a liberty to the co-assessors to take their turns. Wherein he would draw a man on, and allure him, to speak upon such a subject, as wherein he was peculiarly skilful, and would delight to speak. And for himself, he contended no

man s observations, but would light his torch at every man's candle. His fame is greater, and sounds louder in foreign parts abroad, than at home in his own nation. . . . Concerning which I will give you a taste only, out of a letter written from Italy (the Storehouse of refined wits) to the late Earl of Devonshire which states that 'This Lord (Bacon) is more and more known and his books here (Italy) more and more delighted in; and those men that have more than ordinary knowledge in human affairs, esteem him one of the most capable spirits of this age, and he is truly such.' "

As showing the curious ideas prevailing in those days even in the mind of an educated Divine the following gives an insight into the mentality of that time. Rawley says: "It may seem the moon had some principal place in the figure of Bacon's nativity; for the moon was never in her passion, or eclipsed, but he was surprised with a sudden fit of fainting; and that though he observed not, nor took any previous knowledge of the eclipse thereof, and as soon as the eclipse ceased, he was restored to his former strength again."

Dr. Abraham Cowley, whose Poem has been referred to and is given below, was one of the original Fellows of the Royal Society along with Petty and Evelyn. Other Founders of that great Academy of Science, such as John Wallis the Mathematician, and Robert Boyle the Chemist and Physicist, acknowledged Bacon as the originator of their plan, and Bishop Sprat, its Historian, wrote "the foundation of the Royal Society . . . a work well becoming the largeness of his wit to devise."

Philosophy the great and only Heir
  Of all that Human Knowledge which has bin
Unforfeited by Man's rebellious sin.
  * * * * *
Who to the life an exact Piece would make,
Must not from others Work a Copy take;
  No, not from Rubens or Vandike;
Much less content himself to make it like
Th' Ideas and the Images which ly
In his own Fancy, or his Memory.
  * * * * *
From these and all long Errors of the way,
In which our wandering Praedecessors went.
And like th' old Hebrews many years did stray
  In Desarts but of small extent,

Bacon, like Moses, led us forth at last,
The barren Wilderness he past,
Did on the very Border stand
Of the blest promis'd Land,
And from the Mountains Top of his Exalted Wit,
  Saw it himself, and shew us it.
But Life did never to one Man allow
Time to Discover Worlds, and Conquer too;
Nor can so short a Line sufficient be
To fadome the vast depths of Natures Sea;

* * * * *

  Methinks, like Gideon's little Band,
  God with Design has picked out you,
To do these noble Wonders by a Few;
When the whole Host he saw.

* * * * *

Thus you prepar'd; and in the glorious Fight
Their wondrous pattern too you take;
Their old and empty Pitchers first they brake,
  And with their Hands then lifted up the Light.
Lo! Sound too the Trumpets here!
  Already your victorious Lights appear;
New Scenes of Heaven already we espy,
  And Crowds of Golden Worlds on high;
Which from the spacious Plains of Earth and Sea,
  Could never yet discover'd be
By Sailors or Chaldaens watchful Eye.
  Nature's great Works no distance can obscure,
No smallness her near Objects can secure.
  Y' have taught the curious Sight to press
Into the privatest recess
  Of her imperceptible Littleness.
She with much stranger Art than his who put
  All the Iliads in a Nut,
The numerous work of Life does into Atomes shut.
  Y' have learn'd to Read her smallest Hand,
  And well begun her deepest Sense to Understand.

* * * * *

With Courage and Success you the bold work begin;
Your Cradle has not Idle bin:
None e're but Hercules and you[1] could be
At five years Age worthy a History.

[1] This refers to the Royal Society and its Fellows.

BISHOP SPRAT'S " HISTORY OF THE ROYAL SOCIETY "

The history of the Royal Society's earliest work has been set forth in several books, one of the first and most interesting being *The History of the Royal Society of London for the Improving of Natural Knowledge*, written in 1667 by Thomas Sprat, D.D., the Lord Bishop of Rochester. Plate 30 shows the Engraving by Hollar in 1667, used as the Frontispiece to Sprat's Book. The bust in the centre of the engraving represents King Charles II, the figure on the right Francis Bacon, and that on the left Lord Brouncker, the First President of the Royal Society. It will also be noticed that various instruments and pieces of apparatus are shown on the engraving. I referred the question of their identity to the expert opinion of my friend Dr. Charles Singer, F.R.S., the distinguished authority on the History of Science. Dr. Singer has been able to identify on the left of the engraving an instrument for taking the angular distance between two objects and another which was used for measuring the altitude of stars. A clock and a gnomon are also easily distinguishable, whilst a telescope is visible in the background. On the right of the engraving is a thermometer of the type invented about 1600 by Sancto Sanctorio, and a compass, below which is an instrument that can be no other than a theodolite. Two adjustable pendula are also shown. There are also four or five other instruments, the exact nature and use of which are uncertain. On the opening page of the Book, the following words appear : " Let this Book, Intit'led, The History of the Royal Society of London, for the Improving of Natural Knowledge, be Printed. Will. Morrice."

" The Epistle Dedicatory," as my Lord Bishop terms it, is so fascinating that I venture to give at some length what he said, feeling sure his remarks will be of special interest.

The Dedication was To The King, Charles II (1630-1685).—" Sir,—Of all the Kings of Europe, Your Majesty was the first, who confirmed this Noble Design of Experiments, by Your own Example, and by a Public Establishment. An Enterprise equal to the most renouned Actions of the best Princes. For, to increase the Powers of all Mankind, and to free them from the bondage of Errors, is greater Glory than to enlarge Empire or to put Chains on the necks of Conquer'd Nations.

" What Reverence all Antiquity had for the Authors of Natural Discoveries, is evident by the Diviner sort of Honor then conferr'd on them. Their Founders of Philosophical

Opinions were only admired by their own Sects. Their Valiant Men and Generals did seldome rise higher than to Demy-Gods and Hero's. But the Gods they worshipp'd with Temples and Altars, were those who instructed the World to Plow, to Sow, to Plant, to Spin, to build Houses, and to find out New Countries. This Zeal indeed, by which they expressed their Gratitude, to such Benefactors, degenerated into Superstition; yet it has taught us, That a higher degree of Reputation is due to Discoverers, than to the Teachers of Speculative Doctrines, nay even to Conquerors themselves.

"Nor has the True God himself omitted to show his value of Vulgar Arts. In the Whole History of the first Monarchs of the World from Adam to Noah, there is no mention of their Wars, or their Victories; all that is recorded is this, They liv'd so many years, and taught their Posterity to keep Sheep, to till the Ground, to plant Vineyards, to dwell in Tents, to build Cities, to play on the Harp and Organs, and to work in Brass and Iron. And if they deserved a Sacred Remembrance, for one Natural or Mechanical Invention, your Majesty will certainly obtain Immortal Fame, for having Establish'd a perpetual Succession of Inventors.—I am, (May it please Your Majesty), Your Majesty's most humble and most obedient Subject and Servant, THO. SPRAT, Lord Bishop of Rochester."

Quaint as may seem these words to us to-day, there is indeed still as much force and truth in them as when they were uttered. The marvellous recent progress of the World has been largely due to the Scientist, who certainly comprises the Inventor referred to by Bishop Sprat, and not least in these branches of human thought are those who work in "Natural or Mechanical Inventions" or, to use again the Bishop's words, "In Brass and Iron," though the latter metal nowadays plays much the more prominent part.

I wonder what Bishop Sprat would have thought of the American activity of to-day in Inventions? New Patents are being issued at the rate of 600 to 1,000 per week by the American Patent Office, which has 75 million printed copies of about 1½ million Patents, showing the demand for information. These copies of the Specifications of the Inventions are being added to at the rate of 50,000 or more each week. It is the wonderful encouragement given to Inventors in the United States which has so largely helped the rapid development of that Country. A wise and cheap patent law is of the greatest benefit to a Nation.

Since the date when the wise words of the Bishop were

written, the Royal Society has had one long-continued career of usefulness, and owing to the devotion of its Fellows to the cause of Science and Scientific progress, mostly without reward of any kind, there is no Country where Science and Scientific Work are more highly esteemed than in Great Britain, and America has rightly followed our lead and bids fair to surpass us. I know it is often customary to say that we lack appreciation of Scientific merit, but this is not correct. The fight for the cause of Advance and Progress may at times be severe and difficult, but in the long run I venture to think we English and Americans more fully recognise true Scientific merit than any other race.

Indeed, we need not be ashamed but justly proud, and our American Cousins can share in this, too, when it is remembered that from our little Island have come—not mentioning those still with us—such men of the Anglo-Saxon race as Bacon, Newton, Priestley, Dalton, Boyle, Cavendish, Faraday, Davy, Huxley, Tyndall, Spencer, Darwin, Kelvin, Lister, Clerk-Maxwell, Crookes, Rayleigh, and others. As an exceptional reference to one of those still happily with us, and long may this be so, I mention the name—a household one in America not less than in this Country—of Lord Bryce. We Anglo-Saxons owe him a deep debt of gratitude for the magnificent service he has rendered to us in drawing together by thought, word and deed the two English-speaking peoples. On the more Technical side of the work of the Scientist, in which I am specially interested, that of Metallurgy, we have had in the past in the Old World, Dud Dudley, Sturtevant, Pettus, Huntsman, Darby, Kirwan, Cort, Heath, Heaton, Mushet, Whitwell, Bessemer, Siemens, Percy, Sorby, Abel, Bell, Thomas, Gilchrist, Roberts-Austen, Snelus, Stead, Arnold, and others.

In the New World, such men of Science as William Penn, Benjamin Franklin, Count Rumford (Benjamin Thompson), Audubon, Fulton, Louis Agassiz, Alexander Agassiz, Pickering, Newcome, Willard Gibbs, Rowland, Barus, Edison, Graham Bell, Steinmetz, Sterry Hunt, Howe, Holley, Fritz, Westinghouse, Elihu Thomson Michaelson, Asa Gray, Hale, and others —practically all of them Anglo-Saxons. Many of these were or are Fellows of the Royal Society.

The foregoing list is necessarily an incomplete one, and refers almost entirely to those of past times, but the Roll Call in both our Countries is as illustrious as ever, and we Anglo-Saxons may well be proud of our Race. Even if there are names

inadvertently omitted, the foregoing represent some of those who have done the greatest work in the domains of Mathematics, Physics, Electricity, Engineering, Metallurgy, Chemistry, Physiology, Medicine, and other branches of Science.

Some further remarks of Bishop Sprat (1667) are worthy of consideration and are of such interest that even to-day we may well read and profit by pondering over them.

In his *Advertisement to the Reader*, he says, "I must also acquaint him, That in the Title of my Book I have taken a liberty, which may be liable to exception: I have call'd it a History of the Royal Society; whereas the First Part wholly Treats of the state of the Ancient Philosophy; and the Third chiefly contains a Defence and Recommendation of Experimental Knowledge in General; so that it is only the Second Book that peculiarly described their Undertaking. But for my excuse I may allege the Example of many of the Ancients, who have often from the Principal Part of their Works given Title to all the rest."

The Bishop points out that it was the custom of the Wise Men of Ancient times—he was referring to the Assyrians, the Chaldeans and the Egyptians—"to wrap up their Observations on Nature, and the Manners of Men, in the dark Shadows of Hieroglyphics; and to conceal them, as sacred Mysteries, from the apprehensions of the vulgar. This was a sure way to beget a Reverence in the Peoples Hearts towards themselves; but not to advance the true Philosophy of Nature."

He adds, when speaking of the Christian Religion, that "this which had at first appeared so innocent and feasible, and fitted for the benefit of humane Society, which consisted in the plain, and direct Rules of good Life, and Charity, and the Belief in a redemption by one Saviour, was miserably divided into a thousand intricate questions, which neither advance true Piety, nor good manners. Hence arose all the heresies of those times."

Speaking of the want of education at the time, the Bishop refers to one of our ancient English Historians who says "That even amongst the Priests themselves, he was a Miracle that could understand Latin. From that time even down to the Reformation, the Gentlemen of all these Countries, imploying themselves, chiefly in arms, and adventures abroad: and the Books of the Ancients, being either destroyed by the Goths, and Vandalls; or those which escap'd their fury, lying cover'd with dust in the Libraries of Monasteries . . . that all knowledge has been more search'd into, and promoted by them, than by

any other order of men, even from the Egyptians times (whose priests in good part invented, or at least preserv'd the Learning of the East) down to our present Age."

Bishop Sprat, referring to the early Meeting which led up to the formation of the Royal Society, states that "the Meetings continued without any great Intermissions, till about the year 1658, But then being call'd away to several parts of the Nation, and the greatest number of them coming to London, they usually met at Gresham College, at the Wednesdays, and Thursdays Lectures of Dr. Wren, and Mr. Rook: where there joyn'd with them several eminent persons of their common acquaintance: the Lord Viscount Brouncker, the now Lord Brereton, Sir Paul Neil, Mr. John Evelyn, Mr. Henshaw, Mr. Slingsby, Dr. Timothy Clark, Dr. Ent, Mr. Ball, Mr. Hill, Dr. Crone: and divers other Gentlemen, whose inclinations lay in the same way. This Custom was observed once, if not twice a week, in Term time; till they were scatter'd by the miserable distractions of that Fatal year; till the continuance of their meetings there might have made them run the hazard of the fate of Archimedes: For then the place of their meeting was made a Quarter for Soldiers. But (to make haste through those dreadful revolutions, which cannot be beheld upon Paper, without horror; unless we remember, that they had this one happy effect, to open men's eies to look out for the true Remedy) upon this followed the King's Return; and that, wrought by such an admirable chain of events, that if we either regard the easiness, or speed, or blessed issue of the Work; it seems of itself to contain variety, and pleasure enough to make recompense, for the whole Twenty years Melancholy, that had gone before. This I leave to another kind of History to be describ'd. It shall suffice my purpose, that Philosophy had its share, in the benefits of that glorious Action: for the Royal Society had its beginning in the wonderful pacifick year 1660. So that, if any conjectures of good Fortune, from extraordinary Nativities, hold true; we may presage all happiness to this undertaking. And I shall here joyn my solemn wishes, that as it began in that time, when our Country was freed from confusion, and slavery: so it may in its progress, redeem the minds of Men, from Obscurity, uncertainty and bondage."

The qualifications of the Members of the Royal Society are described by the Bishop as follows: "As for what belongs to the Members themselves, that are to constitute the Society; it is to be noted that they have freely admitted Men of different

Religions, Countries, and Professions of Life. This they were oblig'd to do, or else they would come far short of the largeness of their own Declarations. For they openly profess, not to lay the Foundations of an English, Scotch, Irish, Popish, or Protestant Philosophy, but a Philosophy of Mankind. . . . To this purpose, the Royal Society has made no scruple, to receive all inquisitive strangers of all Countries into its number. And this they have constantly done, with such peculiar respect, that they have not obliged them to the charge of contributions; they have always taken care, that some of their Members, should assist them in interpreting all that pass'd, in their publick Assemblies: and they have freely open'd their Registers to them; thereby inviting them to communicate foreign Rarities, by imparting their own discoveries. By their admission of Men

FROM BISHOP SPRAT'S BOOK, SECOND EDITION, PUBLISHED 1702.

of all professions, these two benefits arise : The one, that every Art, and every way of life already establish'd, may be secure of receiving no damage by their Counsels. A thing which all new Inventions ought carefully to consult."

In the Second Edition (1702) of Sprat's *The History of the Royal Society* there is a point of interest to the bibliophile. This is in connection with the watermark on the sheet containing the diagram facing page 233 in the book, and now reproduced. It accompanied the chapter " Experiments of the Recoil of Guns " by William Lord Viscount Brouncker, one of the original Fellows and first President of the Royal Society in 1663, of whom Bishop Sprat says : " William Lord Viscount Brouncker President : which Office has been annually renew'd to him by Election, out of the true judgment, which the Society has made of his great Abilities in all Natural, and especially Mathematical Knowledge."

Curious to say, the paper on which this diagram is printed is evidently of Dutch manufacture, as in the watermark, the Lion with his " ornaments " is exactly the same as on the Dutch florin now used in Holland. My attention was drawn to this curious fact some years ago by a friend in the North of England, the late Mr. D. Jack.

LORD BROUNCKER'S EXPERIMENTS ON THE RECOILING OF GUNS

It is amusing to read Lord Brouncker's words where he says that " When I was commanded by the Royal Society to make some Experiments of the Recoiling of Guns ; In order to the Discovery of the cause thereof, I caused this engine that lyes here before you to be prepared, and with it (assisted by some of the most eminent of this Society) I had divers shots made in the Court of this Colledge, near the length thereof from the mark, with a full charge (about a fourpenny weight) of Powder. I had the honour to make other Experiments with the same Engine, lately at White-hall before His Majesty, and his Highness Royal within the Tilt-yard Gallery, where there is the hearth of a chimney raised a little above the floor, about the distance of thirteen feet from the opposite wall, against which I caused a plank to be placed, and the Engine to be laid first against the middle of the Hearth, that it might not recoil at all, and that

part of the board to be marked against which 'twas levelled, known by a line stretched from the Breech of the Peece unto the Board, directly over the sight and button, and the fire being given (the charge being about eight grains of Powder as before) the Bullet did fully hit the mark. Secondly, the Peece (charged and levelled in the same manner) was laid at the end of the Hearth next the Park, so that very little of the corner R rested against it, and then the Bullets miss'd the mark about an inch and a quarter towards the Park or A. The like being done at the other end of the Hearth, the Bullet then miss'd the mark as much the other way ; and afterwards with double that charge something more, as before I had found it less with a smaller charge." He proceeds to detail the further nature of his experiments, which hardly concern us to-day.

This "Gun," as termed by the then President of the Royal Society in 1663, whilst not representing the larger calibres of those days, invites comparison with the modern British Gun of 18″ calibre, with its projectile weighing about 1½ tons, developing a muzzle energy of 150,000 foot-tons, with a maximum range of probably 30 miles, and capable of perforating hard-faced armour of no less than 41″ in thickness at point blank range. The energy possessed by the projectile when leaving the muzzle is about equal to that possessed by five express trains each weighing 250 tons and travelling with a speed of 60 miles per hour.

THE CHARTER BOOK AND SIGNATURES

In the early days the number of Fellows was small, the present number is 465, of which there are twenty-nine Engineers and eight Metallurgists. Each year the Council selects from the List of Candidates a number not exceeding fifteen to be recommended to the Society for election.

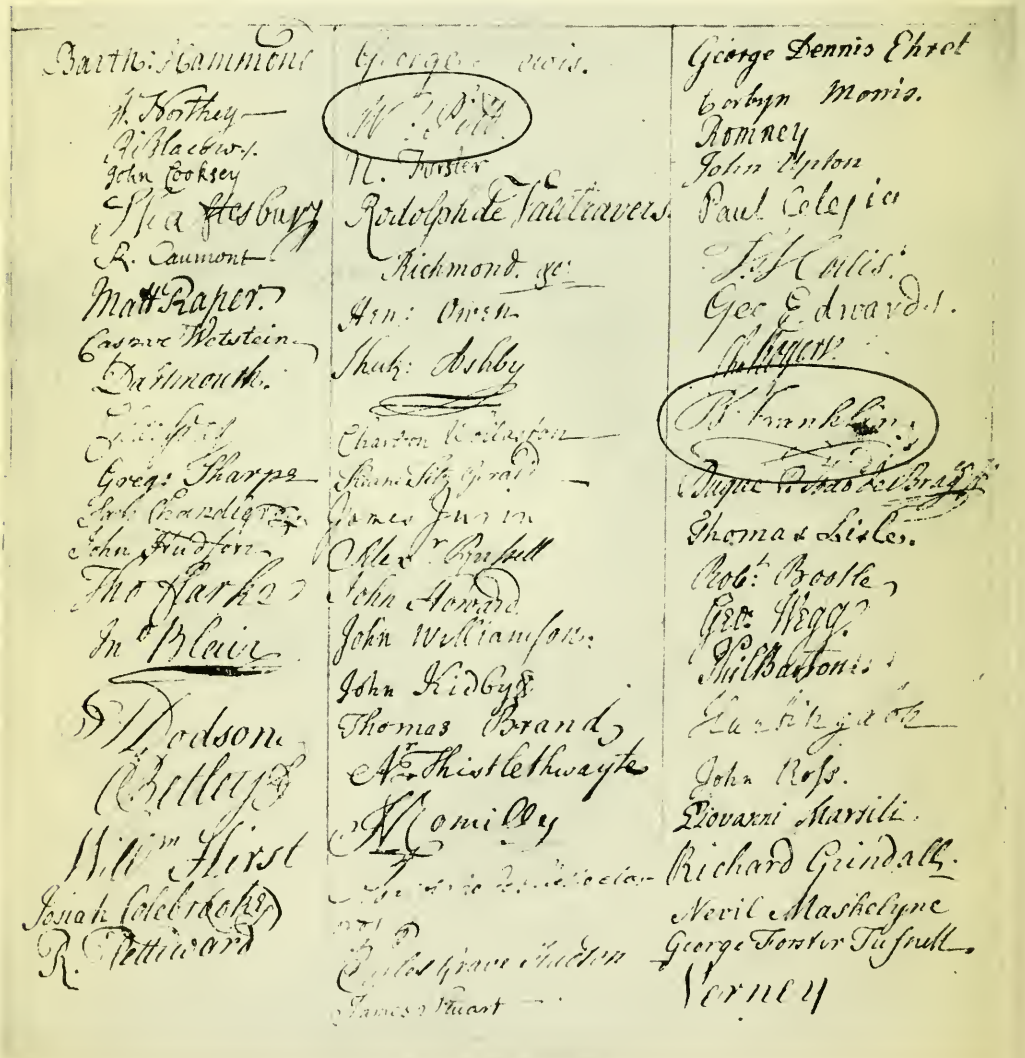
The Charter Book exhibited, which each Fellow must sign before being admitted into the Society, goes back to the year 1660. It is preserved in the Archives of the Society and is used each time a Fellow signs the Charter. In this same Book are to be found the signatures of King Charles II (the Founder), his brother, the Duke of York (afterwards King James II), and the signatures of nearly all our Royal Heads down to the present time. It also contains the signatures of the great Scientists of the past, including the first President of the Society, Lord

FACSIMILE OF ONE OF THE PAGES OF THE CHARTER BOOK OF THE ROYAL SOCIETY.

From the Incorporation of the Society in 1662 down to the present time each Fellow has subscribed to the following Obligation, and has signed his name in this Charter Book.

The Obligation of the Fellows of the ROYAL SOCIETY.

We who have hereunto subscribed, do hereby promise, each for himselfe, that we will endeavour to promote the Good of the Royall Society of London for improving Naturall Knowledge; and to pursue the Ends for which the same was founded; That we will be present at the meetings of the Society, as often as conveniently we can, especially at the anniversary Elections, and upon Extraordinary occasions; and that we will observe the Statutes and Orders of the said Society. Provided that whensoever any one of us, shall signify to the President, under his hand, that he desireth to withdraw from the Society, he shall be free from this Obligation for the future.



The signatures are half full size.

The above are the Signatures (on Page 27 of the Charter Book) of Fellows between the years 1754-1758. Attention is called to the two notable and historic signatures in the ovals, namely, those of William Pitt, afterwards Earl of Chatham, and Benjamin Franklin. It will be of interest to American Engineers to see that these two Great Men signed the Charter Book so near together.

By kind permission of the President and Council of the Royal Society.

Brouncker, Cavendish, Robert Boyle, Wren, Evelyn, who were all original Fellows, elected on the 22nd April, 1663; Newton (11th January, 1671), Priestley (12th June, 1766), Davy (17th November, 1803), Dalton (20th June, 1816), Faraday (8th January, 1824), Wheatstone (21st January, 1836), Duke of Wellington (25th November, 1847), William Harvey (3rd June, 1858), the Great American Benjamin Franklin (29th April, 1756), Louis Agassiz (20th December, 1838).

In Plates 31, 33 and 34 will be found portraits and facsimile signatures of some of the most notable Fellows, including Charles II, James II, Franklin, Pitt, Shaftesbury, Jurin (the Secretary of the Royal Society at that time), Nevil Maskelyne (one of the famous Astronomers Royal), Isaac Newton, Faraday, Joule, Thomson (afterwards Lord Kelvin), Huxley and Tyndall.

MEMBERS OF THE ENGINEERING PROFESSION WHO HAVE BEEN FELLOWS

Regarding Engineers who have been Fellows, in Plate 34 there is the signature of James Watt, with its copperplate character which one cannot but admire, also those of Count Rumford (Benjamin Thompson), Boulton, Telford, Robert Stephenson, Fairbairn and Baker. To Engineers of to-day, the signatures of some of these great Engineers of the past will, I venture to think, be of special interest.

It will be appropriate to make a brief reference to one of our Fellows who played a great part in Engineering, and who was the first President of the Institution of Civil Engineers —Mr. Thomas Telford, F.R.S. He entered upon the duties of that office on the 21st March, 1820. In 1828 he successfully obtained a Charter of Incorporation for the Institution, and at his death left it the sum of £2,000 to establish Premiums and Prizes for Research Work, together with many valuable books and a large collection of documents, the result of his own professional labours. Telford's bequest was the first start in this direction.

Southey jocularly termed him the "Colossus of Roads," for he was consulted by many Governments on this subject. The Polish road from Warsaw to Briesc on the Russian frontier, 120 miles in length, was constructed after his plans, and is said to remain one of the finest roads in Russia.

He closed his career in 1834, at the advanced age of 77, and was buried near the middle nave in Westminster Abbey, the adjoining stone bearing the inscription: "Robert Stephenson, 1859." In his *Lives of the Engineers*, published in 1874, Smiles states, "The son of the Killingworth engine man thus sleeps by the side of the son of the Eskdale shepherd."

Telford's remarkable life is detailed very fully in the work entitled *The Life of Thomas Telford*, written by himself, containing a descriptive narrative of his professional labours; edited by John Rickman, one of his Executors, and published in 1838. This is a book of 700 pages, showing the voluminous nature of his work.

In the light of the enormous steam tonnage now crossing the Atlantic year by year, the great work of Mr. I. K. Brunel, who was made a Fellow of the Royal Society in 1830, should be remembered. His wonderful brain almost succeeded in building a *Mauretania* sixty years ago. No doubt he would have accomplished this, but the Mechanical Engineer and the Metallurgist were not sufficiently advanced in their Science to help him. Brunel also designed the *Great Western* in 1838, the first steamship built to cross the Atlantic, and again the *Great Britain* (1845), the first ocean screw-steamer.

Amongst other British Engineers of renown who were Fellows may be mentioned Smeaton, Rennie, Walker, Rendel, Whitworth, White, Hawksley, Wolfe-Barry, and three who are happily still with us, Kennedy, Matthews, and Unwin.

WILLIAM PENN, BENJAMIN FRANKLIN, AND WILLIAM PITT (EARL OF CHATHAM)

Nearly every one of the eminent men of Science in my Country and many from America too, also those of other Nationalities, who have passed down the long lane of time, have been Fellows. There is, too, a small number of Fellows elected for their eminence in other branches of human knowledge, but as a Metallurgist and Engineer I have not attempted to deal with these.

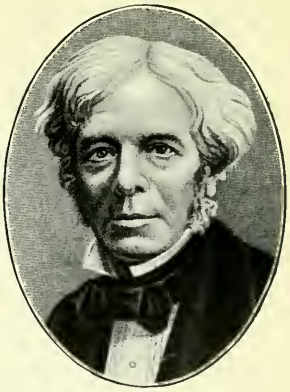
Of special interest to Americans will be the name of Mr. William Penn, son of Admiral Penn. He was made a Fellow on the 9th November, 1681. Attached to his record are the words "Founder of Pennsylvania."

The illustrious American, Mr. Benjamin Franklin, from

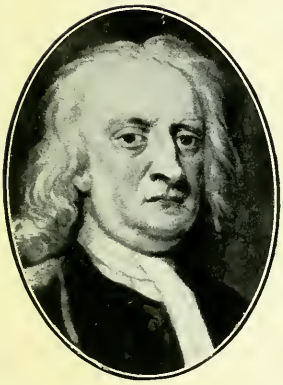
THE FOUNDER, AND SOME OF THE PAST NOTABLE FELLOWS OF THE ROYAL SOCIETY.

(Most of these are given by kind permission of the Council of the Royal Society.)

SIR HUMPHRY DAVY
1778-1829



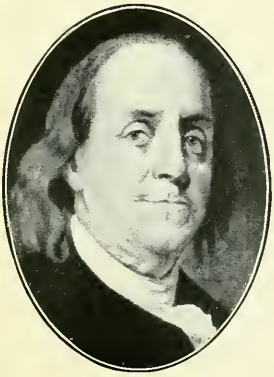
MICHAEL FARADAY
1791-1867



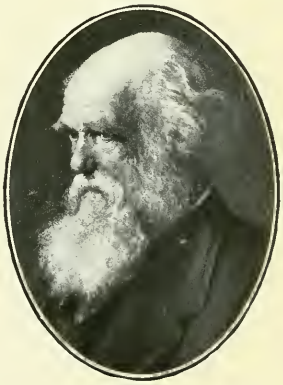
SIR ISAAC NEWTON
1642-1727

CHARLES II.
The Founder
1630-1685

SIR CHRISTOPHER WREN
1630-1723



BENJAMIN FRANKLIN
1706-1790



CHARLES DARWIN
1809-1883

Philadelphia, was, in 1753, awarded the Copley Medal, the highest honour of the Royal Society. In making the presentation, the President said: "This mark of distinction is doubly due to Mr. Franklin; it is due to him as a Philosopher it is due to him as a man. His public spirit, his modesty, goodness, and benevolence have long been conspicuous and the effect of them long felt in the Country where he resides." Three years afterwards, that is, on April 29th, 1756, Franklin was elected a Fellow. When visiting England in 1766, Franklin was curious to see how persons were admitted to the Society. He inspected his own Certificate and said this was "worded very advantageously for me, and signed by Lord Macclesfield, then President; Lord Parker; and Lord Willoughby." His name was entered on the List with a vote of Council that he was not to pay any entrance fee.

In 1767 an unusual course was taken, and a great compliment paid, in asking him to appear before the House of Commons. The ability he displayed, and the valuable information he placed before that Body, greatly enhanced his reputation.

Franklin was in London in the year 1768, during a time when there was much political commotion, with riots and injury to property. In one of his letters he recounts that he had seen "the mob requiring gentlemen and ladies of all ranks, as they passed in their carriages, to shout for Wilkes and Liberty. Coal-heavers and Porters pulling down the houses of coal-merchants that refused to give them more wages. Soldiers firing amongst the mobs and killing men, women, and children." Notwithstanding this turmoil, the Philosophers met and dined at the Royal Society Club as they had been wont to do.

In the great coal dispute of this year it is correct to say that much better temper has been displayed on both sides. I believe that in England no riotous acts have been committed on the workers' side, which is greatly to their credit. If we are to have these disputes, at any rate let us have them without riots or bloodshed.

I take this opportunity of thanking another American Institute which bears the great name of Benjamin Franklin—the Franklin Institute of Philadelphia, Pa., founded in his honour so long ago as 1824. It has done splendid work in America on behalf of Scientific development. This Institute has been kind enough to recognise my Discoveries and Inventions of Manganese Steel, Low Hysteresis Steel, and other special Alloy Steels, by their awards to me of the Elliot-Cresson Gold Medal and the John Scott Medal.

It will surely be of special interest to our American friends to know that William Pitt (afterwards Earl of Chatham) and Benjamin Franklin signed the Charter Book of Fellowship on exactly the same page, that is, page twenty-seven, in fact within a few inches of each other. This is shown on Plate 31, which is a facsimile of that particular page. Pitt had been elected a Fellow in 1743, but for some reason not now known he did not actually sign until ten years later.

Whilst Pitt's signature does not appear to show any special distinctive mark, it is curious to note that of Benjamin Franklin is accompanied by most wonderful flourishes and curves, apparently proceeding from the last letter " n " of his name. To a caligraphist this probably betokens some special mental characteristic. I have had the total length of the whole of the flourish measured, and to be quite accurate it is exactly nine inches!

Pitt, sometimes termed " Pitt the Elder," and afterwards Earl of Chatham, was one of, if not the greatest of the Anglo-Saxon orators and statesmen of the 18th Century. He always spoke out strongly against the arbitrary and harsh policy of the Government towards what were then termed the American Colonies, and warmly urged an amicable settlement of all the differences. His last effort on 7th April, 1778, was, as we all know, an historic one. He came down to the House of Lords and in a stirring oration secured a majority for his motion, but it was his last effort for, exhausted by speaking, on rising again to reply to a query addressed to him by the Duke of Richmond, his physical powers suddenly failed. He fell back into the arms of his friends, and was carried away from the House by his second son, William, who, five years later, was himself Prime Minister. His death occurred a short time afterwards, on May 11th, 1778.

Another great American, Benjamin Thompson, who afterwards became Count Rumford, was also a Fellow. It was he who founded the Royal Institution of Great Britain and gave £1,000 to the Royal Society for the purpose of instituting a Medal to be given every second year as a Premium for the most important Discovery or most useful improvement in Heat or Light, " preference being always given to such Discoveries as shall tend most to promote the good of mankind."

I do not propose to deal here with the present work of the Royal Society and its many modern ramifications, the aid it gives to the Government in administering Research Grants, also the great Scientific work it controls at the National Physical Laboratory—so ably conducted for many years by Sir Richard

Glazebrook, F.R.S., to whom the Nation owes a debt of gratitude, and now by Sir Joseph Petavel, F.R.S. Those further interested will find valuable information in the following books : *The Royal Society, or Science in the State and in the Schools*, by Sir William Huggins, K.C.B., O.M. (1906) ; *The Record of the Royal Society* (1912) ; *The Signatures in the First Journal Book and the Charter Book of the Royal Society, being a facsimile of the Signatures of the Founders, Patrons, and Fellows of the Society from the year* 1660 *down to the present time* (1912) ; *Annals of the Royal Society Club*, by Sir Archibald Geikie (1917) ; *Annals of the Philosophical Club of the Royal Society*, by T. G. Bonney.

Quite recently the Prince of Wales was elected to the Society, and I need hardly add is one of our most popular Fellows. America, too, shares in this admiration for one so young and yet so wise, this Prince of Ambassadors as he has been rightly termed.

No reference, too, to the Royal Society of to-day and its work is complete without mention being made, at any rate, of two of its most important Fellows, Professor C. S. Sherrington, now President, who has done such remarkable and original work in Physiology ; we are proud of his name and fame, and also of our immediate Past-President (1915-1920), Sir Joseph J. Thomson, whose great scientific work is known and renowned throughout the World. I may add that it is the custom, as far as possible, for the Presidential Chair to be occupied in turn by Fellows representing not the same but different branches of Science.

IMPORTANCE OF SCIENTIFIC RESEARCH

Sir Richard Gregory, the able Editor of *Nature*, in a recent leading article dealing with Research and National Progress, rightly pointed out the importance of the aid of Research to human progress in all branches. When preparing my notes for this Address I was quite unaware of Sir Richard's article, in which he, too, refers to Francis Bacon's " Solomon's House," believed to be, as I have already stated, the scheme he had in mind to found what became and is now the Royal Society. Those belonging to this " House," the Fellows, have ever devoted themselves, as Bacon foreshadowed and intended, to the application of experiments, now known as and termed " Research," " to draw out of them things of use and practice for man's life and knowledge."

I have brought before your notice the interesting statements about our Society by Francis Bacon himself, Bishop Sprat and others, because they show that whilst the years roll by, the minds of men, naturally modified by the environment of each particular age, still remain much as they were. It is now 259 years since our Incorporation, yet the influence of Bacon and such men as Sprat was in the same direction as ours to-day, that is, to improve human conditions both mental and physical. This can only be done little by little, line upon line, precept upon precept; by improving our mental philosophy and striving to reach higher and still higher in human thought and its application to our lives.

Lucretius in his Poem on *The Nature of Things* in B.C. 57, showed that the advance of human thought takes place not suddenly but gradually. Slow as may seem the development, it is there and always proceeding. It is this nature of work which the Royal Society endeavours to encourage. Faults the Society may have, but its motto, "Nullius in verba," truly indicates its aims.

Despite errors, as some of them seem to us to-day, this great Poem of Lucretius remains amongst the most remarkable examples of prophetic insight in the history of our race. Amongst the wise views he expressed there is one regarding the sequence of Inventions—the basis, it will be remembered, upon which Bishop Sprat says the Royal Society was founded, "the establishment of a perpetual succession of Inventors," that is, in its widest term—which is indeed worth quoting:

> "Man's earliest arms were fingers, teeth and nails.
> And stones and fragments from the branching woods;
> Then copper next; and last, as latest traced,
> *The tyrant, iron.*"

Thus did this great Poet prophesy one of the most fruitful achievements of Man in modern Science, and this applies in the highest degree to the development of the last fifty years, that is, the phenomenal advances in human knowledge with regard to this wonderful metallic element "Iron," which is indeed in war, as we have experienced only recently, "the tyrant iron." Much of my life, and that of many others, has been spent upon its study, hence my admiration for this wonderful metal. We have learned much about it, but there is more and more still to be learned; the field this Metal affords for Research seems as wide as the ocean.

Stephen Laing in his *Human Origins* points out that Iron was no doubt known at a very early period, but it was extremely scarce, and even as late as Homer's time was stated to be so valuable that a lump of it constituted one of the principal prizes at the funeral games of Patroclus.

The antiquity of Iron is shown in a valuable paper on *Iron in Ancient Egypt*, by Mr. J. A. Wainwright in the Cairo Scientific Journal, August 1914. He refers to known specimens of Iron found in the inner joints of the Great Pyramids—pickaxes, spearheads, ferrules, sickles and a helmet. Whence this Iron was obtained, he states, is a most difficult question to answer.

Wainwright also points out the particularly interesting fact that the name of Iron in Ancient Egypt is a strange one, for it is called the Stone of Heaven, and the name by which this metal was known in Ancient Babylonia was "Ana-bar," also meaning Stone of Heaven. This probably indicates the then rarity of Iron and surely, too, that Meteorites furnished in those very early days one, at any rate, of the sources of the metal.

In my Papers on "Sinhalese Iron and Steel of Ancient Origin," read before the Royal Society, also the Iron and Steel Institute, in 1912, details will be found of my own experiments with regard to the composition of ancient specimens of Iron, including those taken from the actual Iron Pillar at Delhi. This Pillar represents an Iron forging 23 feet 8 inches in length and weighing about 6 tons, and in the days when there were no steam hammers or forges! The only explanation of this wonderful specimen of Iron is that it must have been welded together in sections, though there are no signs of this on the Pillar itself. The study of the metal Iron is of the most fascinating nature. Anyone who has worked upon this element, without doubt the prime metal of civilisation, knows how many are the surprises its examination has revealed and still holds in store. The great advances which have resulted from Research work upon Iron show the benefits arising from Scientific study and Research.

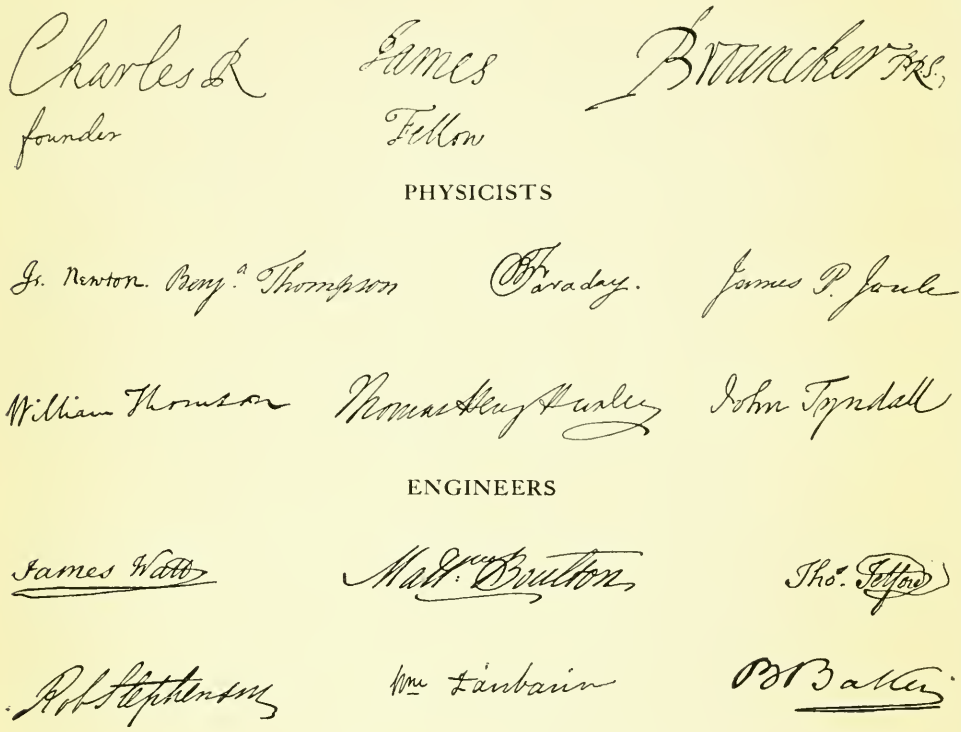
Whilst Iron was known a long way back in the history of mankind, it is only within the last generation that our knowledge of it has progressed so greatly, in fact, one may say in a manner in which few people, if anyone at all, living fifty years ago would have deemed credible. The modern development of the use of Iron, whether in the form of Cast Iron, Wrought Iron or Steel, has been at a phenomenally rapid rate. It has not been an evolution of the ordinary kind; that is to say, up to about 1878 Alloy Steels were hardly known. There had previously

been shown great mental prescience on this subject by such men as Agricola (Germany), Dud Dudley (England), Pettus (England), Swedenborg (Sweden), Huntsman (England), Rinman (Sweden), Cronstedt (Sweden), Bergman (Sweden), De Elhuyar (Spain), Vauquelin (France), Heath (England), Mushet (England), Berzelius (Sweden), Berthier (France), Percy (England), and finally by Faraday himself, who carried out important experiments of great promise on Alloys of Iron with other elements. It was not, however, until the decades 1870 to 1890 that there occurred the great advances and tremendous burst of activity in Metallurgical Science, of which we see the striking results and benefits to-day.

PLATE 34.

SIGNATURES OF SOME OF THE PAST NOTABLE FELLOWS OF THE ROYAL SOCIETY, COLLECTED FROM DIFFERENT PAGES OF THE CHARTER BOOK.

(By kind permission of the President and Council of the Royal Society.)



The signatures are half full size.

CHARLES II
Founder and First Fellow of the Royal Society, 1664.

JAMES (DUKE OF YORK)
Second Fellow 1664, and afterwards James II.

LORD BROUNCKER
The First President of the Royal Society 1663.

PHYSICISTS

ISAAC NEWTON
Discoverer of the Law of Gravitation 1671.

BENJAMIN THOMPSON
Afterwards Count Rumford. Founder of The Royal Institution, and the Rumford Medal 1779.

MICHAEL FARADAY
Discoverer of the Laws of Electrical Induction 1824.

JAMES P. JOULE
First to accurately measure the Mechanical Equivalent of Heat 1850.

WILLIAM THOMSON
Afterwards Lord Kelvin. Very eminent Physician and Mathematician 1851.

THOMAS HENRY HUXLEY
Biologist, Philosopher and Man of Letters 1851.

JOHN TYNDALL
Distinguished Experimentalist and brilliant writer 1852.

ENGINEERS

JAMES WATT
Inventor of the Steam Engine 1785.

MATTHEW BOULTON
Eminent Engineer and Co-partner with Watt 1785.

THOMAS TELFORD
The First President of the Institution of Civil Engineers in 1820. Effected great advances in road construction 1827.

ROBERT STEPHENSON
Distinguished Engineer 1849.

WILLIAM FAIRBAIRN
Designer of the Menai Straits Bridge 1850.

BENJAMIN BAKER
Designer of the Forth Bridge 1890.

The date affixed to each name represents the year in which the Charter of Fellowship was signed.

Section XVII

CONCLUSION

A wise and particularly interesting saying by Joseph Glanvill came before me quite recently, and I should like you also to know it. Glanvill, who became Prebendary of Worcester, lived about 1650 A.D., that is, not far short of three hundred years ago. He was one of the leaders of thought of that time, in fact was one of the early Fellows of the Royal Society, being admitted in the year 1664. His facsimile signature will be found on page 7 of the Charter Book of the Royal Society exhibited this evening.

Glanvill made the following remarkable prediction about the metal, Iron, with which you and I are so intimately concerned in our daily lives. He said : " Iron seemeth a simple metal, but in its nature are many mysteries, and men who bend to them their minds shall, in arriving days, gather therefrom great profit, not to themselves alone, but to all mankind." Indeed a prophetic utterance from so far back as 1650.

Iron has indeed been, and will continue to be, of the highest profit to the World. Its study will always be a fascinating one, and if we progress as much in the future in our knowledge of it as in the past, then the advance will be even more marvellous. Unhesitatingly I claim that Iron is by far the most important metal to Civilisation. The entire absence of what we call the precious metals, Gold and Silver, would but little affect our comfort. Take away Iron, however, and we go back to the dark ages.

I need therefore make no excuse for presenting to you so fully this evening the various facts I have done, not only Scientific and Technical, but also other facts regarding this wonderful Metal—Iron.

In conclusion, what should be our watchword for the future ? It is hard for even the wisest amongst us, whether Statesman or ordinary mortal, to see clearly through the mist and fog of to-day's tremendous World depression. One point, however, stands out, that in this age of fierce competition we must each try to the utmost of our ability to do our duty in our various situations of life.

We may not all reach the greatest heights. Every soldier in the trenches was not a General. It was the ordinary soldier

—rank and file—who by doing his duty enabled the war to be won. Therefore let it be remembered that those of us occupying even the humblest position in life can still, by doing their duty, help on our day and generation.

A short time ago, whilst paying a visit to the ancestral home of Lord Chichester at Lewes, near Brighton, I came across a remarkable proverb, which I should like to mention.

Lady Chichester was showing some of the interesting family heirlooms. Amongst them was a Prayer Book dated 1646, and used by Oliver Cromwell, in fact in it his initials were written by himself. On one of the opening pages were the following words in Latin—these are shown in Plate 32: "Qui cessat esse melior cessat esse bonus." A free translation of this might be rendered as: "He who ceases to aim at better things will cease to do good things." Indeed a fine motto for all of us to contemplate and ponder over, whether individually or nationally. Let the spirit of these words be not only the aim of our Society, as I am sure it has been in the past, but of Sheffield generally; then I have no fears for our position in the great unknown future, difficult as this may now seem.

CLASSIFIED LIST OF PAPERS

BY

SIR ROBERT A. HADFIELD, BT., F.R.S.

The following Table represents a Summary of the Classified List of Papers and Addresses, 135 in number, read by Sir Robert A. Hadfield, Bt., between the years 1888 and 1922 :—

		Number of Papers.
1.	Manganese Steel	14
2.	Alloys of Iron with Silicon, Aluminium, Chromium Nickel, Tungsten, Copper, Cobalt, Molybdenum and other Elements	12
3.	Sound Steel	12
4.	Early History of Crucible Steel	2
5.	Ancient Iron and Steel	5
6.	Mechanical Tests	3
7.	Hardness and Hardening	6
8.	Electrical and Magnetic Properties	7
9.	Production of Magnetic Alloys from Non-Magnetic Materials	2
10.	Corrosion of Iron and Steel	4
11.	Effect of Low Temperatures upon Iron, Steel and Alloy Steels	3
12.	Metallography	3
13.	Pyrometers	2
14.	X-Ray Examination of Iron, Steel and other Materials	4
15.	Fuel	3
16.	Addresses : Presidential	7
17.	Addresses : Not Presidential	26
18.	Progress of Metallurgy	2
20.	Education	2
21.	General	9

Full particulars of these papers will be found in Appendix II of the book compiled by Mr. R. E. Neale, B.Sc., Editor of Pitman's Technical Primers, entitled " The Metallurgy of Iron and Steel "—being an outline of the Development of Modern Practice in the Metallurgy of Iron and Steel, and its bearing on the Conservation of Metal and Fuel ; based mainly on the work and papers of Sir Robert A. Hadfield, Bt., D.Sc., D.Met., F.R.S.

DESCRIPTION OF EXHIBITS

OLD SPECIMENS OF MANGANESE STEEL PRODUCED IN THE VARIOUS HADFIELD RESEARCHES IN 1882–1890

These include tools and implements made to ascertain its suitability for various purposes. Some of the specimens are only shown because of their historical interest, not because the steel has a commercial application in these directions. Most of them are the identical specimens exhibited at the Institution of Civil Engineers 30 years ago, that is in February, 1888, when the original paper was read by Hadfield.

1. Photograph of Extract from the Author's experimental book dated 7th September, 1882, showing the extract relating to his first researches which resulted in the discovery of Manganese Steel.

2. Specimens from the original Iron-Manganese Alloy Research Ingots made in 1882.

3. Photographs of early applications of Manganese Steel made in 1882 to 1892.

4. Brittle Iron-Manganese Alloy. This Alloy ($4\frac{1}{2}$ per cent. Mn.) can be pounded with a hand hammer.

5. Art Castings illustrating the fluidity of Manganese Steel in its molten state.

6. Implements, including Axe Heads, Adzes, Grids, Links, Horse Shoes, Draw Bars, Plough-Shares, Paper Knife, Pokers.

MODERN APPLICATIONS OF MANGANESE STEEL

1. Shrapnel Helmets of British, French and German design illustrating the superiority of the first-mentioned type made of Manganese Steel. The extraordinary strength and ductility of the material make it ideal for this purpose. The Helmets supplied to the British soldiers during the Great War were made of Manganese Steel.

2. Shrapnel Bullets used in testing helmets; before and after firing.

3. Body Shields of Manganese Steel.

4. Models of Dredger Pins. These Models were made from actual Pins which had been in use on the same Dredger.

(*a*) Manganese Steel, 10 months wear.
(*b*) Ordinary Steel, Case Hardened, 3 months wear.

5. Mining Wheel of Manganese Steel flattened cold under the tup.

6. Selection of photographs illustrating applications of Manganese Steel, including (*a*) solid steel breaker, (*b*) special railway track work, (*c*) screen plate, (*d*) rolled rails, (*e*) Dredger tumbler castings, (*f*) Dredger Buckets, (*g*) Gyratory Crusher parts.

7. Tensile Test Bars of Manganese Steel (*a*) before testing, (*b*) partially tested, Maximum Stress 60 tons, Elongation 50 per cent., (*c*) fully tested, Maximum Stress 65.6 tons, Elongation on 6 in. 71.1 per cent.

8. Tensile Test Bar and stress strain diagram of this Test Bar made by Professor E. G. Coker, F.R.S., University College, London.

9. Drillings of Manganese Steel and Ordinary Steel; 750 grs. are removed from ordinary Carbon Steel and only 11 grs. from Manganese Steel in the same time.

10. Rail of Manganese Steel, bent double cold.

11. Crusher Jaw of Manganese Steel. This Jaw has crushed 18,000 tons of hard ganister rock, and by reversing in the Crusher, is capable of a still longer life. Ordinary Jaws of Chilled Iron under similar conditions are worn out after crushing an average of 5,500 tons.

12. Diagram comparing of the heating and cooling curves of Manganese Steel and Carbon Steel, showing the entire absence of critical points in the former.

NON-MAGNETIC QUALITIES OF MANGANESE STEEL

Exhibits illustrating various applications for which the non-magnetic qualities of Manganese Steel render it suitable.

1. Sample showing the alloy in both magnetic and non-magnetic condition in the same bar.

2. Large powerful Hand Magnet and Keepers of Manganese Steel and pure Iron, demonstrating the non-magnetic character of the former material.

3. Apparatus for determination of Specific Magnetism. With this apparatus the specific magnetism is determined in a simple way by the pull of a hand magnet.

4. Diagram illustrating the greatly improved action of the Compass when using non-magnetic steel for Wheelhouses and Steam Trawlers.

5. Photographs showing special applications of non-magnetic Steel, including (*a*) bulkhead plates for warships, (*b*) cylindrical Steel Casings for Submarine Mines.

LOW HYSTERESIS STEEL

1. Small Transformer constructed of Hadfield's Low Hysteresis material made in 1903 by the Sheffield Corporation Electric Supply Department. This small Transformer was the first made of this material, which is now universally used for all electrical purposes where low magnetising losses are essential, as in Transformers. Its use has resulted in the saving of very large sums annually in this country, the United States, and on the Continent. Mr. T. D. Yenson, Head of the Laboratory of the Westinghouse Electric Company, estimates the total saving up to date has been about £80,000,000, that is, as he adds "sufficient to pay for the cost of the Panama Canal."

2. Photographs of 40 k.w. and 60 k.w. Transformers constructed of Hadfield's Patent Low Hysteresis Steel, made in 1905 and 1906, and since in continuous use on the Sheffield City Corporation Electrical Supply. The tests made periodically on these Transformers down to the present time prove the non-ageing quality of this material, that is, the energy losses diminish, whereas with ordinary material they seriously increase.

LOW TEMPERATURE RESEARCH

1. Collection of specimens and test bars illustrating Sir Robert Hadfield's Paper read before the Iron and Steel Institute in May, 1905, "Experiments relating to the Effect on the Mechanical and other Properties of Iron and its Alloys produced by Liquid Air Temperatures."

ALLOYS RESEARCH

1. Diagrams showing Tensile qualities of Alloys of Iron with Manganese, Nickel, Chromium, Silicon, Aluminium, Tungsten. The researches illustrated by the diagrams, represent in some cases the first systematic investigation into the physical and mechanical effect of alloying elements upon Iron.

GENERAL SCIENTIFIC EXHIBITS

1. Chippings from Ancient Iron Pillar of Delhi. A feature of this remarkable Pillar is the resistance it has offered to atmospheric corrosion extending over a period of more than sixteen centuries.

2. Show Cases of Elements and Alloys connected with the manufacture of modern Special Steels.

3. Model of United Engineering Society's building, New York City.

4. Facsimile copy of the Charter Book of the Royal Society.

5. Large Temperature Chart showing the principal Melting and Freezing Points, also other important Metallurgical Temperatures based on the latest available data.

LITERATURE

1. The Author's various Research Papers, upwards of 130 in number.

2. Part of the Hadfield Collection, with Catalogue, of old Metallurgical Books, dating from 1505 A.D.

MEDALS

The ten Gold and two Bronze Medals, three Premiums, also other Awards, presented from 1888 to 1921 to Sir Robert Hadfield, by Scientific and Technical Societies in Great Britain, France and America for his various Research work.

Copies of this Address, fully illustrated, may be obtained from Messrs. Charles Griffin & Co., Ltd., Publishers, 12, Exeter Street, Strand, London, or from Mr. W. H. Seed, 50, Church Street, Sheffield, and other Booksellers.

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